Interreg
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INNOBIOVC

Sustainability Assessment Tool REPORT

Deliverable D.1.1.2

Summary
The SAT report describes the methodology that allows the quantification of social, economic and ecological sustainability gains on the regional, value chain and product/service levels.

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Deliverable description

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List of abbreviations

AHP	Analytic Hierarchy Process
CBE JU	Circular Bio-based Europe Joint Undertaking
IECS	Innovation Express Call scheme
PESTEL	Political, Economic, Social, Technological, Environmental and Legal analysis
PLA	Polylactic Acid
SAT	Sustainability Assessment Tool
TRL	Technology Readiness Level
VCG.AI	Value Chain Generator AI

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Executive Summary

The **INNOBIOVC Sustainable Assessment Tool Report (D.1.1.2)** offers a detailed overview of the Sustainability Assessment Tool (SAT) created by the INNOBIOVC project, funded by the European Union's Interreg Alpine Space Program. This tool is designed to evaluate, validate, and promote sustainable practices within the circular bioeconomy of the Alpine region, in alignment with the European Green Deal and the UN Sustainable Development Goals.

The report begins by placing the INNOBIOVC project within the larger framework of the circular bioeconomy. It highlights the strategic value of bio-based products in the Alpine region, which is known for its biomass resources and sustainable traditions. It also identifies the transition challenges, such as the need for innovative business models, technological advancements, and supportive policies. Next, the report uses the PESTEL framework to analyse the bio-based context in the Alpine area, examining political, economic, social, technological, environmental, and legal factors.

The report's core focuses on the SAT, a multi-criteria decision-making tool that evaluates the environmental, social, and economic performance of bio-based value chains. The SAT offers insights into functionality, including data analysis, visualisation, and identification of sustainability hotspots. Moreover, the SAT's benchmarking feature allows companies to compare their performance against industry standards, guiding them towards best practices and optimisation.

Afterwards, the report describe how the SAT is integrated with other INNOBIOVC tools like the Innovation Express Call Scheme (IEC24) and the Value Chain Generator (VCG.AI). The IEC24 provides financial support for cross-border bio-based innovations, while the SAT ensures these innovations meet sustainability criteria. The VCG.AI uses artificial intelligence to connect businesses within the circular bioeconomy, complementing the SAT by fostering regional cooperation and driving sector growth.

Finally, the report discusses SAT's dissemination and future development, highlighting the efforts to raise awareness including social media, newsletters, and promotional videos.
Finally, the report focused on user engagement, crucial for refining the SAT with potential future expansions to cover additional value chains and improve the user interface.

1. Introduction

1.1. General Context

The transition from a fossil-based to a circular bio-based economy is increasingly recognised as a driver for regional competitiveness, playing a crucial role in achieving the objectives outlined in the **European Green Deal** and the **UN Sustainable Development Goals.**

Bio-products and **bio-based value chains** are promising paths to embrace a broader valorisation and value-addition approach, involving a sophisticated network of processes and stakeholders contributing to industrial competitiveness with environmental and socio-economic benefits within the local and European levels. At the EU level, many strategies, such as the **EU Circular Economy Strategy**[1], target the circular bioeconomy and aim for resource efficiency, via the establishment of industrial symbiosis.

The linear production systems become circular when materials (e.g. sludge, industrial wastewater, household and organic waste), which are usually disposed of, become further used in the product cascade, minimising or eliminating wastes and avoiding competition for starting biomasses with food. However, business models designed under **the circular bioeconomy framework** must tackle numerous technological, environmental, and economic challenges to maintain long-term a competitive edge over canonical fossil-based routes such as reliable and scalable biomass access, expenses associated with quality and supply, and conversion efficiency. According to the bioeconomy report by the JRC centre (**Fig.1**), the most significant use of biomass in the bioeconomy sector is for food and feed, highlighting the need for more opportunities to produce value-added products. Biomass for energy (bioenergy) remains the primary renewable energy source in the EU, accounting for nearly 60% of the total. The heating and cooling sector is the largest consumer, using about 75% of all bioenergy.

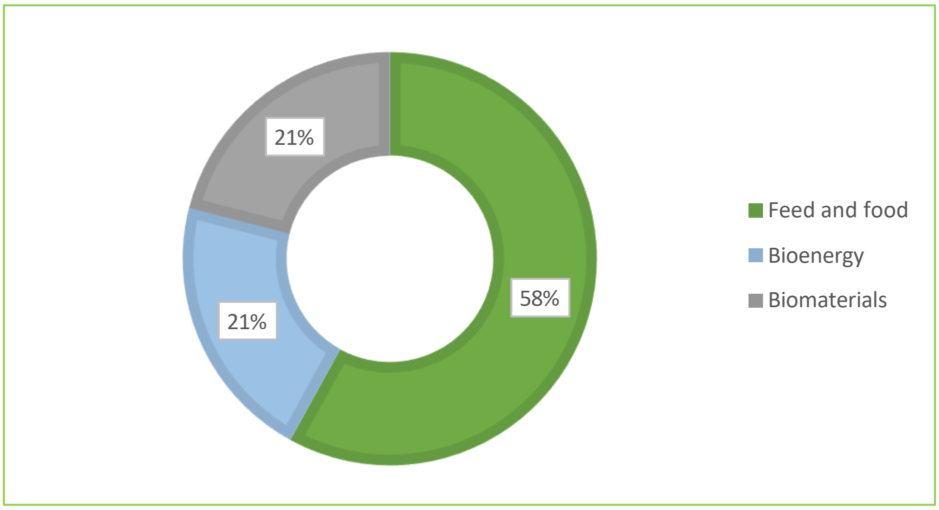

***Figure 1**: Europe total biomass use, from "How big is the bioeconomy" JRC report, 2020*

Approximately 40% of the EU's land area is woodlands (forest land and permanent crops), with a similar share being agricultural land, which is 60% cropland and 40% grasslands[2].
For this reason, **bio-based products** have the potential to contribute to EU objectives of sustainable growth by reducing reliance on fossil fuels. The demand for bio-based products is also increasing among investors and consumers mainly because of the increasing interest in products' environmental and health aspects. Studies showed investors consider bio-based barriers and risk as the factors related to feedstock, customer preferences, regulatory concerns and competition aspects vis-à-vis traditional products[3].
Land use, impact on biodiversity and ecosystems, water consumption, greenhouse gas emissions and food competition are just some of the evaluation criteria to consider in the economic decision-making process and the industrial feasibility study[4]. A **sustainable bio-based value chain** must integrate industrial

sectors in a symbiotic logic, where the added value and benefit can be distributed from primary raw material producers to technology providers and brand owners[5]. However, developing a circular added value chain is still challenging (**biomass circularity** is only **11%** across the EU[6]), undermined by potentially risky investments and existing regional supportschemes that stop at national borders.

1.2. Circular Bioeconomy in the Alpine area: the **INNObioVC** Project

The Alpine Space, with its vast and diverse selection of natural resources and advanced technological infrastructure, stands as a prime candidate for the development and implementation of circular bio-based solutions. This region, comprehending approximately **27.97 million hectares** (data from InnobioVC project) of forested land, is abundant in biomass resources, particularly lignocellulosic materials, which are central to emerging bio-based value chains. The **INNObioVC** project, part of the Interreg Alpine Space Program, has the objective of transforming these biological resources into high-value products that address climate change challenges while enhancing regional sustainability.

The Alpine Area's technological landscape is supported by a robust **network** of research centres, universities, and companies, all dedicated to advancing bio-based innovations. The INNObioVC project capitalizes on this network to implement several key technologies designed to optimize the development of circular bio-based value chains. Among these technologies are the **Innovation Express Call Scheme (IECS), the Sustainability Assessment Tool (SAT), and the Value Chain Generator (VCG.AI).** Each of these tools plays a specific role in ensuring the success and scalability of bio-based solutions within the Alpine region.

- The **IECS** is a financial instrument designed to facilitate cross-border collaboration by leveraging existing regional funding programs. This scheme aims to overcome the barriers to incremental production by providing necessary financial support to projects that are in the later stages of development. By aligning regional funding with the needs of the circular bioeconomy, the IECS promotes interregional cooperation, which is vital for scaling up innovative solutions and enhancing the competitiveness of the Alpine regions.
- The **SAT**, on the other hand, is a comprehensive tool for evaluating the sustainability of bio-based value chains. It assesses environmental, social, and economic impacts to determine the overall feasibility and scalability of tester value chains. By providing detailed insights into the sustainability performance of bio-based products, the SAT enables stakeholders to make informed decisions and optimize their strategies for maximum impact. This tool is essential for identifying the most effective pathways for integrating circular principles into the bioeconomy, ensuring that new solutions contribute positively to the environment and society while remaining economically viable.
- The **VCG.AI**, utilizing artificial intelligence, offers another layer of support by helping businesses identify and connect with potential partners within the circular bioeconomy value chain. This technology assists companies in navigating the complex network of stakeholders and resources necessary for developing and scaling bio-based solutions. By facilitating these connections, VCG.AI enhances collaboration and innovation, driving the creation of robust and interconnected bio-based value chains. The integration of AI into this process not only streamlines partner identification but also accelerates the development of effective circular bioeconomy solutions.

Together, these technologies address various challenges faced by the circular bioeconomy sector in the Alpine Area. By targeting value chains with a higher Technology Readiness Level (TRL), INNObioVC ensures that efforts are focused on solutions with greater potential for impact and tangible results. This strategic approach helps overcome obstacles related to production scale-up and market adoption, advancing the implementation of circular bioeconomy practices across the region.
International partnerships and **cross-regional cooperation** play a critical role in the success of

the INNObioVC project. These collaborative efforts facilitate the exchange of knowledge, resources, and best practices, driving the development of demonstration projects and job opportunities within the circular bioeconomy sector. By working together, stakeholders from different regions can share insights, overcome common challenges, and create scalable solutions that benefit the entire Alpine Area. The project's emphasis on cross-border collaboration highlights the importance of a united approach to achieving sustainability and innovation goals.

The **integration** of technologies such as IECS, SAT, and VCG.AI enhances the project's ability to support and scale bio-based solutions, while also addressing key challenges related to sustainability and market adoption.

1.3. Purpose and Scope of the Report

The **primary purpose** of this report is to address the **quantification of sustainability gains** at the Alpine regional level, providing a macro perspective on how localized efforts contribute to overall sustainability. This analysis aims to paint a clear picture of the effectiveness and impact of sustainability measures within the Alpine area, thereby offering valuable insights into the broader implications of such initiatives.

Following this regional assessment, the report delves into a detailed exploration of **the Sustainable Assessment Tool (SAT)**, elucidating its design, functionality, and the guiding principles behind its development. The SAT is a focal component of the methodology, developed to provide a simplified but comprehensive evaluation of value-chain sustainability metrics. Its design incorporates sophisticated algorithms and assessment criteria to accurately measure social, economic, and ecological gains, ensuring a holistic evaluation of sustainability projects. The functionality of the SAT is explained in depth, highlighting its ability to integrate diverse data sources and generate actionable insights. The principles guiding the SAT's development are also discussed, highlighting the tool's alignment with best practices and innovative approaches in sustainability assessment.

Additionally, this report examines the **integration** of the SAT with the IEC24 and VCG.AI tools. This integration is crucial for fostering new value chains within the Alpine Space, as it enhances the SAT's capabilities and extends its application to a broader range of sustainability initiatives.

Understanding and **identifying the most promising bio-based products** with significant growth potential in the Alpine region has been a central focus of the INNObioVC project. Work Package 1 of the project involved a thorough study to quantify the social, economic, and ecological framework in the Alpine area, with the first findings detailed in Deliverable 1.1.1 "ANALYTICAL REPORT." This initial study provided an understanding of the regional context and set the stage for subsequent analyses. In the **second phase**, the results from the preliminary *market analyses*, *PESTEL* (Political, Economic, Social, Technological, Environmental, and Legal) and *SWAT* (Strengths, Weaknesses, Opportunities, and Threats) were assessed, integrated with the *LCA* analyses on the environmental impacts of the bio-based products and incorporated into the innovative Sustainable Assessment Tool (SAT). The integration of these analyses into the SAT further refines its capability to measure and interpret sustainability gains, offering a more detailed and accurate valuation of the impacts of sustainability initiatives. The report thus aims to provide a comprehensive view of the SAT's methodology, its application in the Alpine region, and its integration with key frameworks like IEC24 and VCG.AI.

This project is co-funded by the European Union through the Interreg Alpine Space programme

2. Analysis of the Bio-Based Context in the Alpine Area

Understanding and identifying the best bio-based value chains with the most significant growing potential in the Alpine area has been one of the main focuses of the INNObioVC project. As the world increasingly moves toward sustainable development, the bio-based industry, which relies on renewable biological resources for products, is gaining traction. In this context, the Alpine region presents unique opportunities and challenges due to its specific geographical, social, and economic characteristics. To capitalize on these opportunities, a **detailed examination** of the bio-based sector in this region is essential. This analysis not only identifies the most promising value chains but also examines the broader factors affecting their development and sustainability.

2.1. PESTEL Results Analysis

In this comprehensive discussion, we explore the results obtained from the **PESTEL** analysis, which was crucial in shaping our understanding of the region's bio-based potential. The PESTEL analysis provided a comprehensive overview of the significant forces impacting the development of the Alpine bio-based industry. By examining political, economic, social, technological, environmental, and legal factors, this analysis is crucial in identifying key development priorities and supporting the creation of the SAT. Among these factors, the following aspects stand out as particularly influential.

2.1.1. Political Factors

The political landscape in Europe plays a significant role in shaping the bio-based products market, driven largely by the **Bioeconomy Strategy**[7], which serves as a central policy tool. This strategy supports the growth and acceleration of bio-based products in the market, aligning with the broader green transition goals of the European Union (EU). By encouraging the development and use of bio-based chemicals, materials, and energy sources, the EU aims to reduce reliance on fossil resources. Several key policy measures have been identified as critical to the growth of the bio-based sector:

- Renewable Energy Directive (RED II)[8]: RED II promotes the use of renewable resources for energy and fuel production, including bio-based feedstocks. By setting ambitious targets for renewable energy use, RED II directly supports the bio-based chemicals and proteins sectors.
- Circular Economy Action Plan[9]: Part of the European Green Deal, this action plan promotes the circular use of resources, including bio-based materials and chemicals. It aims to reduce waste and environmental impact, which aligns with the goals of the bio-based sector.
- Chemicals Strategy for Sustainability[10]: Also, as part of the European Green Deal, this strategy focuses on making chemicals safer and more sustainable. It advocates for the use of bio-based and biodegradable chemicals as alternatives to traditional, potentially harmful chemicals.

These policies and directives collectively create a favourable political environment for the development and adoption of bio-based products in Europe. However, the complexity of the regulatory landscape, including compliance with regulations like REACH[11] (Registration, Evaluation, Authorisation, and Restriction of Chemicals) and CLP[12] (Classification, Labelling, and Packaging), adds challenges for companies operating in this sector. Navigating these regulations requires significant resources and expertise, particularly for small and medium-sized enterprises (SMEs) that make up a large portion of the bio-based sector in the Alpine region.

2.1.2. Economic Factors

Economic considerations are critical in the bio-based products sector, particularly concerning the cost of production and market competitiveness. The economic environment in Europe and the Alpine region presents both opportunities and challenges for the bio-based industry.

- Funding and Investment: The Horizon Europe program, especially the CBE JU, is a significant source of funding for bio-based projects. This financial support is crucial for advancing research and development (R&D) and scaling up innovations to large-scale demonstration plants. However, securing this funding is often competitive, requiring companies to demonstrate a strong potential for innovation and market impact[13].

- Market Size and Growth: The bio-based chemicals sector in Europe generates approximately 10,6 billion euros annually, while the bio-based plastic polymers market represents around 3,4 billion euros[14]. Despite these significant figures, bio-based products still hold a small market share compared to their fossil-based counterparts. This disparity is primarily due to higher production costs and competitive disadvantages. For instance, the economies of scale achieved by fossil-based industries make it challenging for bio-based products to compete on price.
- Raw Material Costs: The production costs of bio-based products are highly sensitive to the prices of raw materials, such as corn starch, sucrose, and other agricultural inputs. Fluctuations in these prices, driven by factors like droughts, seed prices, and labour shortages, can significantly impact the profitability of bio-based products. This volatility is particularly concerning in the Alpine region, where the agricultural sector is subject to the vagaries of the mountainous climate[15].
- Energy Costs: The production of bio-based products, particularly bioplastics, requires substantial energy input, both in electricity and process heat. Therefore, fluctuations in industrial electricity and natural gas prices can heavily influence manufacturing costs. In regions like the Alps, where energy costs can be higher due to the remote and mountainous terrain, this factor is even more pronounced[16].
- Consumer Demand and Market Dynamics: Although there is growing consumer awareness of the environmental benefits of bio-based products, purchasing decisions are often influenced by the cost-effectiveness of these products compared to traditional fossil-based alternatives. The high costs associated with the life cycle of bio-based products, including waste management and disposal, can deter consumer adoption unless offset by technological advancements or policy incentives[17].

The economic factors outlined above suggest that while there is significant potential for the growth of the bio-based industry in the Alpine region, realizing this potential will require **addressing key economic challenges.** Strategies such as improving production efficiency, securing stable raw material supplies, and increasing consumer acceptance through education and incentives will be essential.

2.1.3. Social Factors

Social trends and consumer behaviour are increasingly influencing the bio-based products market, particularly in terms of sustainability and health concerns. The Alpine region, with its unique cultural and social dynamics, presents specific opportunities and challenges for the bio-based sector.

- Consumer Awareness and Environmental Concerns: There is a growing awareness among consumers about the environmental impact of traditional fossil-based products. This has led to increased interest in bio-based alternatives, particularly in sectors like packaging and food production. However, consumer choices are still largely driven by cost considerations, with bio-based products often being perceived as more expensive[17]. In the Alpine region, where there is a strong cultural emphasis on environmental conservation and sustainable living, this awareness is even more pronounced. However, the challenge remains in translating this awareness into purchasing decisions, particularly in the face of economic constraints.
- Health and Dietary Trends: The rise of veganism and concerns over the health impacts of animal proteins have spurred demand for plant-based and other bio-based protein sources[18]. The global plant-based protein market is expected to grow significantly, reflecting a broader shift in consumer preferences towards more sustainable and health-conscious food choices. This trend is particularly relevant in the Alpine region, where there is a strong tradition of plant-based and organic food consumption. However, the challenge lies in ensuring that bio-based proteins meet the taste, texture, and nutritional expectations of consumers.
- Cultural Acceptance and Food Safety: The production of bio-based proteins, especially those derived from fermentation or insect-based sources, faces challenges related to consumer

acceptance. Concerns about allergens and the safety of novel food products are significant barriers that need to be addressed through stringent regulations and effective communication strategies. In the Alpine region, where traditional food cultures are strong, introducing novel bio-based food products may require careful consideration of cultural sensitivities and preferences[19].

- Public Awareness and Education: The success of bio-based products also hinges on public understanding and support. Educating consumers about the benefits of bio-based products and the importance of proper waste management practices is essential for fostering a more sustainable consumption pattern. In the Alpine region, where there is a strong tradition of environmental education and community engagement, there is an opportunity to leverage these cultural strengths to promote the adoption of bio-based products[3].

The social factors discussed above highlight the importance of consumer behaviour and cultural acceptance in the growth of the bio-based industry. In the Alpine region, strategies that align with local cultural values and emphasize the environmental and health benefits of bio-based products are likely to be most effective.

2.1.4. Technological Factors

Technological advancements are crucial for the growth and competitiveness of the bio-based products sector. Innovations in production processes, waste management, and product development can significantly impact the efficiency and sustainability of bio-based products. The Alpine region, with its specific geographical and economic characteristics, presents unique technological challenges and opportunities.

- R&D and Innovation: Continuous investment in R&D is vital for overcoming the technological challenges associated with bio-based product manufacturing. This includes developing more efficient fermentation processes for bio-based proteins, improving the energy efficiency of bio-based plastic production, and enhancing the environmental performance of bio-based chemicals. In the Alpine region, where research institutions and universities have a strong focus on sustainability and environmental sciences, there is significant potential for innovation in the bio-based sector. Collaborative efforts between academia, industry, and government can drive the development of cutting-edge technologies that enhance the efficiency and sustainability of bio-based production processes[20,21].
- Process Optimization: Technological improvements aimed at optimizing production processes are key to reducing the costs and environmental impact of bio-based products. For instance, optimizing fermentation processes to increase yield and reduce contamination risks can lower production costs and improve the market viability of bio-based proteins[19]. In the Alpine region, where small-scale, artisanal production methods are common, there is a need for technologies that can be adapted to smaller production scales without sacrificing efficiency or sustainability.
- End-of-Life Solutions: Developing effective waste management and recycling technologies for bio-based products is essential for ensuring their sustainability. The lack of established waste management systems for bio-based plastics, for example, poses a significant challenge. Technological solutions that facilitate the composting, recycling, or biodegradation of these products are critical for their long-term success. In the Alpine region, where waste management infrastructure may be less developed in remote areas, there is a particular need for innovative solutions that can be implemented at the local level[22].
- Regulatory Compliance: Technological advancements are also needed to ensure compliance with stringent regulations, such as those governing the safety and labelling of food products or the environmental impact of chemicals. Innovations that can meet or exceed regulatory standards will have a competitive advantage in the market. In the Alpine region, where the regulatory environment can be complex due to the intersection of national and EU regulations, technology-driven compliance solutions can help companies navigate this landscape more effectively.

2.1.5. Environmental Factors

The environmental impact of bio-based products is a multifaceted issue, including a range of benefits and challenges that need to be carefully assessed to ensure overall sustainability.

- Climate Change Mitigation: Bio-based products offer significant potential for climate change mitigation. One of the most substantial advantages is the reduction of greenhouse gas emissions during their production. Traditional fossil-based processes are notorious for their high carbon footprints, whereas biotechnological methods used in bio-based product manufacturing can dramatically lower these emissions. Estimates indicate that by 2030, these advanced biotechnological processes could potentially reduce CO2 equivalent emissions by a staggering 1 billion to 2.5 billion tonnes annually[23]. This reduction is achieved through the use of renewable feedstocks and the incorporation of carbon capture technologies, which help sequester CO2 that would otherwise contribute to global warming.
- Resource Efficiency: In terms of resource efficiency, bio-based products often fare better than their fossil-based counterparts. They typically require less non-renewable energy and result in lower greenhouse gas emissions. However, this isn't a universal benefit. The production processes of bio-based products can also lead to environmental issues such as eutrophication—the excessive richness of nutrients in water bodies, which can cause harmful algal blooms—and stratospheric ozone depletion. These impacts are closely linked to agricultural practices, including the use of fertilizers and land management techniques. Therefore, addressing these potential negative effects requires careful optimization of agricultural practices and sustainable resource management[24].
- Sustainable Biomass Production: The challenge of ensuring sustainable biomass production is a critical aspect of the bio-based sector's environmental footprint. Biomass must be sourced in a way that does not contribute to deforestation, loss of biodiversity, or unsustainable land use changes[25]. The need for sustainable practices extends to monitoring land use changes, protecting natural habitats, and promoting biodiversity-friendly cultivation methods. Certification schemes and sustainability standards play a crucial role in guiding and verifying the responsible sourcing of biomass.
- End-of-Life Impact: The end-of-life phase of bio-based products is another crucial consideration for their environmental impact. While bio-based materials often decompose more easily than conventional plastics, improper disposal can still result in pollution and environmental harm. The development of effective disposal, recycling, and composting systems is essential to minimize any adverse effects. Innovations in biodegradable materials and advancements in recycling technologies are vital to enhancing the overall sustainability of bio-based products, ensuring they contribute positively to environmental conservation[22].

2.1.6. Legal Factors

The legal landscape governing the bio-based products sector is intricate and covers various aspects from production to safety and environmental stewardship.

- Regulatory Compliance: Companies operating in the bio-based sector must adhere to an extensive array of regulations that ensure safety, environmental protection, and consumer health. As previously mentioned, regulations such as REACH[11](Registration, Evaluation, Authorisation, and Restriction of Chemicals) and CLP[12](Classification, Labelling, and Packaging) are fundamental in overseeing the registration, assessment, and labelling of chemicals. These regulations aim to promote the safe use of chemicals and encourage the substitution of hazardous substances with safer alternatives. Compliance with these regulations involves rigorous testing and documentation, which can be both time-consuming and costly but is essential for market access and consumer safety.
- Food Safety and Labelling: The production of bio-based proteins, particularly those derived from innovative sources like insects or lab-grown meat, is governed by stringent food safety

regulations. The General Food Law[26] and Novel Foods Regulation[27] set high standards for safety assessments before these new protein sources can be introduced to the market. Allergen labelling[28] is another critical aspect regulated under the Food Information to Consumers Regulation[28], ensuring that consumers are fully informed of potential allergens in bio-based protein products. This regulatory framework is crucial for maintaining public health and confidence in new food technologies.

- Waste Management: The legal framework surrounding waste management is vital for supporting the sustainability of bio-based products. Key regulations such as the Waste Framework Directive[29] and the EU's Circular Economy Action Plan[9] establish guidelines for waste reduction, reuse, recycling, and disposal. These laws are designed to minimize environmental impact by promoting a circular economy approach, which emphasizes the efficient use of resources and the reduction of waste. Compliance with these regulations requires the development of effective waste management strategies and technologies that support the lifecycle management of bio-based materials.
- Intellectual Property and Patents: Protecting intellectual property (IP) is a critical legal factor for companies involved in the bio-based sector. Securing patents for new bio-based innovations is essential for protecting proprietary technologies and maintaining a competitive edge. The patent process involves complex legal and technical considerations and navigating this landscape can be both challenging and costly. Effective IP protection not only safeguards a company's innovations but also encourages investment in research and development by providing legal assurances against infringement.

2.2. Analysis of Bio-Based LCA Results

Life Cycle Assessment (LCA) studies play a critical role in **evaluating the sustainability of bio-based products**, particularly in the unique environmental and socio-economic contexts of the Alpine region.

Several notable studies provide comprehensive assessments of the environmental and social impacts of bio-based energy and products in this fragile ecosystem. For instance, a significant study titled *"LCA of Environmental and Socio-Economic Impacts Related to Wood Energy Production in Alpine Conditions: Valle di Fiemme (Italy)"* offers an in-depth analysis of the woody biomass supply chain in the region. This research focuses on the production of biomass energy for heating plants, examining both environmental factors such as greenhouse gas emissions, land use, and air quality, as well as socio-economic factors like job creation and community well-being. By assessing the entire lifecycle of biomass energy, from wood harvesting to energy generation, this study underscores the potential of biomass energy as a renewable resource in regions like Valle di Fiemme, while also highlighting the need for careful management to ensure long-term sustainability[30].

Another important study, *"Environmental and Climate Change Impacts of Eighteen Biomass-Based Plants in the Alpine Region"*, provides a comparative analysis of biomass facilities using LCA methodologies. This research offers valuable insights into the environmental sustainability of different biomass plants, playing a crucial role in promoting sustainable bioenergy practices in the Alpine region. The findings serve as a resource for policymakers, energy producers, and environmental stakeholders, helping to mitigate the environmental impacts of energy production in sensitive, high-altitude ecosystems like the Alps[31].

In addition to specific case studies, a broader **review of LCA literature studies** from 2016 to 2019 reflects the growing focus on bioeconomy strategies in Europe, particularly in Italy. This review highlights the increasing application of LCA as a tool to monitor environmental performance in bio-based sectors, with a focus on agricultural and forestry products, bioplastics, and bioenergy. The methodologies employed in these studies reveal an evolving sophistication in assessing the environmental impacts of bio-based products. By utilizing different LCA methods, researchers aim to provide a more holistic evaluation of product life cycles, emphasizing the importance of this approach in shaping sustainable bioeconomy strategies. This broader review also highlights Europe's leading role in advancing LCA applications, offering key insights for informed policymaking and sustainable business practices[32].

The **social dimensions** of LCA are gaining traction as researchers integrate social factors into sustainability assessments through the Social Life Cycle Assessment (SLCA). SLCA complements traditional environmental LCA by evaluating social impacts such as labour conditions, human rights, and community well-being. This holistic approach is particularly important in bio-based product development, where balancing environmental and social factors is essential for long-term sustainability. By incorporating SLCA, businesses and policymakers can better understand the broader societal impacts of their decisions, fostering more responsible production methods that benefit both the environment and the people involved throughout the supply chain[33].

Collectively, the LCA studies highlight that despite the potential benefits of bio-based products, these present several **environmental challenges**, particularly in the Alpine region. One of the primary environmental impacts is **greenhouse gas (GHG) emissions**, where bio-based products generally exhibit a lower GHG footprint compared to fossil fuels. A systematic analysis revealed that emerging bio-based products have on average, a GHG footprint that is 45% lower than fossil-based products. However, variability among individual products means that achieving net-zero emissions remains elusive. This suggests that while bio-based products can contribute to climate change mitigation, their overall benefits depend on specific product characteristics and production methods. **Eutrophication** is another concern, with biomass cultivation often requiring fertilizers that can lead to nutrient runoff, causing algal blooms and oxygen depletion in aquatic ecosystems. Some bio-based products have been shown to exacerbate eutrophication by up to 369%, emphasizing the need for careful nutrient management in biomass production[34,35]. **Land use** change is also a significant issue, as the cultivation of biomass can lead to habitat loss, biodiversity reduction, and soil degradation. LCA studies stress the importance of evaluating land use impacts to fully understand the sustainability of bio-based products[31,36]. Furthermore, the extraction and processing of biomass can **strain natural resources** like water and soil, with intensive agricultural practices potentially depleting water supplies and degrading soil health over time[30,36].

In conclusion, while bio-based products offer promising paths for reducing GHG emissions and promoting sustainability in the Alpine region, they also pose significant environmental challenges. To address these complexities, comprehensive LCA studies are essential for understanding the specific environmental and socio-economic impacts of bio-based products and guiding sustainable practices in the Alpine region. Through careful management and informed decision-making, the potential benefits of bio-based products can be realized while mitigating their environmental risks.

3. Sustainability Assessment Tool (SAT)

Following this regional assessment of the bio-based industry, the report delves into a detailed exploration of **the Sustainable Assessment Tool (SAT)**, elucidating its design, functionality, and the guiding principles behind its development. The SAT is a focal component of the methodology, developed to provide a simplified but comprehensive evaluation of value-chain sustainability metrics. This tool is set to become an invaluable resource for stakeholders dedicated to enhancing the sustainability of their value chains. By utilizing this tool, stakeholders will be equipped with the necessary data and guidance to make informed decisions, drive positive change, and foster sustainable practices throughout their operations.

3.1. Sustainability Assessments "State of the Art"

To gain a comprehensive understanding of the current "state of the art" in the field of Sustainability Assessment and its application to bio-based value chains, literature analysis was conducted using the Web of Science database. The search focused on publications related to "sustainability assessment" and "assessment of bio-based value chains." This analysis provided insights into prevailing trends, methodologies, and research gaps within the field.
The results of the bibliographic analysis indicate that current research on sustainability assessment heavily emphasizes environmental sustainability, primarily through methodologies such as Life Cycle Assessment (LCA). **LCA** is widely used to quantify environmental impacts, ranging from resource use and emissions to the overall environmental footprint of processes and products. However, this focus often overlooks the multidimensional nature of sustainability, where social and economic dimensions are integral but frequently underrepresented in the assessments.
Despite this environmental bias, the analysis identified notable examples of more holistic approaches that attempt to integrate the environmental, social, and economic pillars of sustainability. These "more comprehensive" assessments demonstrate a growing recognition of the need to balance all aspects of sustainability. Among the publications identified, the following three papers stand out as exemplary cases of integrative sustainability assessment methodologies:

- Lokesh K., **Bridging the Gaps for a 'Circular' Bioeconomy: Selection Criteria, Bio-Based Value Chain and Stakeholder Mapping**[24]. This paper exploits a systematic approach based on two-tier multi-criteria decision analysis (MCDA), useful in supporting the identification of promising bio-based value chains significant to the EU plans for the bioeconomy. Their identification is followed by an elaborate mapping of the value chains to visualize and foresee the strengths, weaknesses, opportunities and challenges attributable to those bio-based value chains. A systematic review of 12 bio-based value chains is performed, prevalent in the EU, mapping interactions between the different stages, chain actors, employed conversion routes, product application and existing/potential end-of-life options.
- Petit, Gaëlle and Sablayrolles, Caroline and Yannou-Le Bris, Gwenola, **Combining eco-social and environmental indicators to assess the sustainability performance of a food value chain: A case study**[37]. This paper aims to assess the sustainable performance of food products or processes combining LCA, SCR and MADM-specific frameworks. SCR stands for "Social corporate responsibility" and MADM for "Multiple-Attribute Decision-Making framework". CSR is mainly focused on the social pillar of sustainability. This political approach has been instrumentalized through the international standard ISO 26000 to help companies and organizations reduce their externalities on both society and the environment. MADM instead, refers to making preference decisions via assessing a finite number of pre-specified alternatives under multiple and usually conflicting attributes.
- Nirit Havardi-Burger, Heike Mempel, Vera Bitsch, **Framework for sustainability assessment of the value chain of flowering potted plants for the German market**[38].

The primary objective of this paper is to create indicator-based assessment methods that offer valuable insights into the sustainability performance of agricultural value chains for flowering potted plants (FPPs). The assessment focuses on addressing environmental, social, and economic sustainability challenges associated with the entire FPP value chain, from breeding to distribution. A comprehensive framework was established for conducting sustainability assessments within the FPP value chain. The study draws inspiration from the Sustainability Assessment of Food and Agriculture Systems (SAFA) approach. However, it should be noted that SAFA does not encompass all sustainability subthemes, hence the need for a more tailored framework to address the specific complexities of the FPP industry.

3.2. Foundations of the SAT: the MCDMA and AHP methodologies

The Sustainable Assessment Tool (SAT) is grounded in a methodology known as **Multi-Criteria Decision-Making Analysis (MCDMA)**[39], a robust evaluative approach that integrates both quantitative and qualitative factors to inform decision-making processes. MCDMA provides a structured framework for assessing multiple options that may have conflicting impacts on society, the economy, and the environment, allowing for a balanced evaluation of diverse factors. This method is particularly useful in situations where selecting the best alternative among several potential candidates is necessary, as it systematically evaluates different aspects of each option. Commonly considered criteria in many decision-making scenarios include **cost, price,** and **quality of processes.**

MCDMA has been a widely recognized decision methodology since the 1960s, appearing in numerous academic articles and books. The approach is based on two fundamental components: options and criteria. Options represent the alternatives being considered, while criteria serve as the parameters used to evaluate and compare these alternatives. Evaluation criteria can fall into two categories: "maximization" or "minimization," which define the values preferred in the analysis. For "maximization," the worst-case scenario (WC) corresponds to the minimum value in the performance matrix, and the best-case scenario (BC) corresponds to the maximum value. Conversely, in "minimisation" evaluations, lower values are preferred (BC), while the worst-case scenario is associated with the highest value (WC).

To further refine the decision-making process, weights are assigned to each criterion, reflecting their relative importance and indicating priorities within the evaluation. To assign weights, it has been employed the **Analytic Hierarchy Process** (AHP) which allows one to rank or select between a set of alternatives the best one, performing a pairwise comparison of criteria[39,40].
AHP requires the involvement of "decision makers" and follows this scheme (Fig.2):

1. **Define the "goal":** identifying the main objective to be achieved.
2. **Establish the hierarchy:** break down the decision problem into a hierarchical structure including the main objective, criteria, and alternatives (Fig.2). The criteria represent the different factors that contribute to the decision, while the alternatives represent the different options being considered.

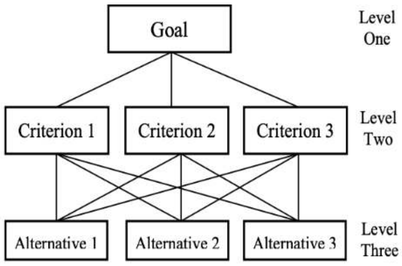

Figure 2: *Sample Hierarchical Tree, Decision Making Using the Analytic Hierarchy Process, Hamed Taherdoost (2017).*

3. **Pairwise Comparisons:** assess the relative importance or priority of each alternative by conducting pairwise comparisons. Each criterion is compared against every other criterion using a scale of relative importance from 1 to 9.
4. **Calculate Weighted Scores:** calculate weighted scores for each alternative, these scores indicate the overall preference of each alternative considering the importance (or "weight") of the criteria.
5. **Consistency Checking:** assess the consistency of the pairwise comparisons to ensure the reliability of the results through the consistency ratio index (CR), which measures the degree of consistency in the judgments made during pairwise comparisons.
6. **Analyse and Interpret Results**

3.3. SAT evaluation criteria – identification

Based on these theoretical principles, we have conducted a field study within our task of the INNOBIOVC project to create the SAT aimed toward biobased products and value chains. To do so, the first step was to determine which factors (criteria) impact the most on the company's part during their entire biobased value chain to build our SAT around the analysis and comparison of those with benchmark data.
The SAT evaluation criteria were developed through a combination of comprehensive research methods, including:

1. **Bibliographic analysis:** A detailed review of existing literature was conducted to identify relevant evaluation criteria. This involved studying previous research, industry reports, academic papers, and other reliable sources that discuss bio-based value chains.
2. **Expert Interviews:** To ensure the criteria were practical and relevant, interviews were conducted with key stakeholders. These included decision-makers and experts (e.g. VEGEA) in the bio-based value chain from both large industries and small and medium-sized enterprises (SMEs). The input from these professionals helped to validate and refine the criteria based on real-world experiences and needs.

This approach ensured that the criteria were both evidence-based and aligned with industry needs. Below are the criteria that were identified:

- **Water consumption:** how many cubic meters of water are consumed to produce 1 ton of final product (m^3/t), water consumption is a key aspect of sustainable development. By tracking water usage, individuals, businesses, and governments can identify opportunities to reduce water waste.
- **Energy consumption:** This indicator helps evaluate not only the environmental impact of the process but also resource management and operation cost saving (Mj/ t).
- **Production volume:** how many tons of product are produced in 1 year (t/y). It provides valuable insights into various aspects of a company's operations, performance, and competitiveness in the market.
- **Profit:** the profit gain from 1 ton of product (€/t).
- **Net profit:** the net profit gain (*total profit – production expenses*) from 1 ton of product (€/t).
- **Gender ratio:** the percentage of women workers in the company.
- **Ratio Input/ Output:** in the context of biomass refers to the efficiency of converting a certain amount of biomass into a final product and resource management. This ratio can vary depending on the specific process or industry involved.

CRITERIUM NAME	MEASUREMENT UNIT	EVALUATION TYPE

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Water consumption	m^3/t	Minimization
Energy consumption	Mj/t	Minimization
Production volume	t/y	Maximization
Profit	€/t	Maximization
Net profit	€/t	Maximization
Gender ratio	/	Maximization
Input/Output	/	Minimization

Table 1: *SAT criteria, measurement unit, and evaluation type.*

Those criteria have been selected among several ones also because able to be measured in any bio-based business, regardless of the final product produced.

3.4. SAT evaluation criteria – weighting

After deciding the criteria, an **AHP survey** was performed on 6 participants, and they were asked through paired comparison questions, which is the most relevant sustainability indicator in a bio-based business, and to give their feedback through the use of a scale which ranges from one to nine (Fig.3), where:

- 1 implies that the two elements are equally important.
- 9 implies that one element is more important than the other one in a pairwise matrix.

Importance Scale	Definition of Importance Scale
1	Equally Important Preferred
2	Equally to Moderately Important Preferred
3	Moderately Important Preferred
4	Moderately to Strongly Important Preferred
5	Strongly Important Preferred
6	Strongly to Very Strongly Important Preferred
7	Very Strongly Important Preferred
8	Very Strongly to Extremely Important Preferred
9	Extremely Important Preferred

Figure 3*: Scores for the importance of variable, Decision Making Using the Analytic Hierarchy Process (AHP); A Step by Step Approach, Hamed Taherdoost (2017).*

The data collected in the interviews were analysed using the *"AHP Excel template with multiple inputs Goepel, Klaus D. (2013),"* which consists of a data elaboration workbook comprising 20 input worksheets for pair-wise comparisons and a summary end sheet to display the results. This template facilitates a structured and systematic approach to decision-making by enabling multiple input analyses, where each worksheet captures the comparative evaluation of sustainability indicators. The final weight for each sustainability indicator, considered in the final ranking, was calculated as the weighted average of the performance value of the individual indicator across each worksheet, as shown in Equation (A). This approach ensures a comprehensive aggregation of expert assessments, allowing for an accurate representation of the relative importance of each indicator.

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$$\frac{\sum_{k=1}^{n} \frac{x_{ij} \times p_i}{p_{tot}}}{100} \quad \text{(A)}$$

- x is the specific score for a criterion (j), in a worksheet (i);
- p is the total of participants considered in the worksheet I;
- p_{tot} is the total of participants with a CR > 45% in the specific category.

Each criterion weight is subsequently multiplied by the criterion value of each value chain, as expressed in equation B where S_{ij} is the value chain-specific score (i) for the sustainability indicator (j), and w_j is the indicator's weight.

$$s_{ij} \times w_j \quad \text{(B)}$$

Finally, the obtained values are summed to obtain an overall score for the benchmark and tested value chains. This latter is expressed in Equation © and is the final value.

$$\sum_{k=1}^{n} s_{ij} \times w_j \quad \text{©}$$

Following the AHP procedure, we were able to determine each criteria weight. Weights are shown below in Table 2 and Figure 4.

CRITERIA	AHP WEIGHT
Water consumption	18,9%
Energy consumption	15,6%
Production volume	5,2%
Profit	1,8%
Net profit	3,4%
Share of females	32,5%
Input/Output	22,6%

***Table 2**: AHP criteria weights.*

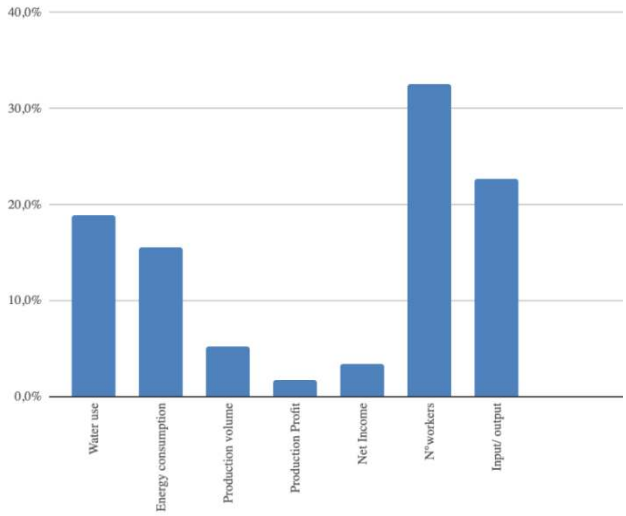

***Figure 4:** AHP weights following the survey analysis.*

3.5. SAT Sustainability Benchmark Data - selection

Starting from the preliminary market analysis detailed in D1.1.1, which was conducted to identify bio-based products with the highest potential to enhance competitiveness in the Alpine area, **10** key bio-based products were selected. This selection was based on their Technology Readiness Level (TRL), relevance within the Alpine space, and current market[41] value, including factors such as selling price and market dynamics prospects. These products were identified as having the most significant potential impact on the growth and sustainability of the Alpine region's economy.

1. **Bio-based lactic acid**. It is a key product in cosmetics as a skin exfoliator and moisturiser in drug manufacturing because of its antibacterial properties and PLA synthesis.
2. **Bio-based acetic acid**. It is commonly used in paints, plastics and glues as a pH regulator and in food industries as a sour agent.
3. **Bio-based 1,2 propanediol**. It is suitable for insulators with antifreeze properties, and, in the food industry, is employed as a humectant and preservative agent.
4. **Bio-based succinic acid**. It is utilized as a green and bio-based solvent in various chemical processes, such as in the production of resins and coatings and in the cosmetics field as an exfoliating and skin-conditioning agent.
5. **Polylactic Acid (PLA).** It is used to produce filaments for extrusion, disposable tableware, soil fabrics and household products (toys, reusable bags, garbage bags).
6. **Bio-based glycerol**. It is a key ingredient in food, used as a humectant and sweetener, medical as an excipient, paints and coating applications.
7. **Bio-based glutamic acid**. It is produced from biomass through fermentative pathways. It is used in medical applications to treat neurological conditions and neurodegenerative diseases, in the food industry as a flavour enhancer, and in the animal feed industry.
8. **Polyhydroxyalkanoate (PHA).** It is used in the plastic industry because of its biodegradability and compostability.
9. **Bio-based adipic acid**. Used mainly for nylon production and as a food additive.
10. **Bio-based lysine.** It is produced from biomass through fermentative pathways. It is a common additive in animal feed, especially for livestock, poultry and hair care industries.

In the second period of task 1.1, we proceed with the identification of the **5 most relevant biobased products** in the Alpine region (Lactic acid, Succinic acid, Glycerol, Polymers (mainly PLA), Amino acids (mainly lysine)), then, the study concentrated on establishing values for each benchmark criteria to be integrated into the SAT. We have selected and grouped the biobased products into three general categories:

- *bio-based platform chemicals* (intermediates between raw materials and final products used to link different biorefinery concepts),
- *bio-based plastic polymers*
- *bio-based proteins*

and further evaluated with an in-depth analysis.

BIO-BASED PRODUCTS	MARKET VALUE
Lactic acid	1.100 million
Succinic acid	110,4 million
Glycerol	2.400 million
PLA	624,97 million
Glutamic acid	9.540 million

LEGEND
Platform Chemical
Plastic polymers
Proteins

***Table 3**: Bio-based most relevant products in the Alpine region*

The benchmark values were determined by calculating averages from a diverse range of data, incorporating both large industries with established market experience and smaller enterprises. This approach ensures that the analysis is comprehensive and representative of the entire sector.

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3.6. SAT Sustainability Benchmark Data – In-depth analysis

A product description and a market analysis are given below for each of the selected bio-based products, to study how the product's business can be improved in the future and what is holding the product back from being widely available and successful on the market[42].

3.6.1. Lactic Acid

3.6.1.1. Product Description and Market Value

Lactic acid, also known as 2-Hydroxypropanoic acid, is a naturally occurring organic acid widely used in various industries, including chemicals, food, cosmetics, medical, and pharmaceuticals. Its extensive applications stem from its status as an environmentally friendly product, as it is produced from renewable resources through a sugar fermentation process and is valued for its growth-promoting properties and metabolic activity. Additionally, lactic acid is commonly used to produce Polylactic Acid (PLA), a compostable and biodegradable thermoplastic polymer derived from renewable sources.

Thus, lactic acid plays a crucial role as a platform chemical in the biobased economy, with significant growth potential. The global market for lactic acid reached USD 6.09 billion in 2022 and is projected to grow from USD 7.14 billion in 2023 to USD 22.75 billion by 2030, with a compound annual growth rate (CAGR) of 18.0%[43].

3.6.1.2. Biomass

The production of lactic acid from biomass Utilising a variety of organic matter obtained from organisms, such as lignocellulosic biomass, food waste, and microalgae[44].

Because lignocellulosic biomass is abundant and renewable, it is a popular feedstock for lactic acid production. It consists of elements including agro-waste, municipal solid waste (MSW), forest biomass (wood and wood processing wastes), agricultural residues, and inedible plant components. These sources are abundant in cellulose and hemicellulose, which can undergo hydrolysis into sugars that can be fermented to create lactic acid[45]. The most promising agricultural residues are:

- **Barley Extract:** Used as a nutrient source in the fermentation process for d-lactic acid production, providing essential nutrients required by lactic acid-producing bacteria.
- **Whey Protein Hydrolysate:** Derived from the liquid remaining after milk has been curdled and strained, it serves as another nutrient source that supports the growth of lactic acid-producing bacteria.
- **Soybean Meal:** A byproduct of soybean oil extraction, utilized as a nitrogen source in the fermentation medium, promoting bacterial growth and lactic acid production.
- **Cottonseed Meal:** Like soybean meal, it is used as a nutrient source in the fermentation process. It is a byproduct of cottonseed oil extraction and provides essential nutrients for bacterial growth.
- **Alfalfa Fiber and Soya Fiber:** These fibres have been evaluated for their potential in lactic acid production through simultaneous saccharification and fermentation (SSF) processes. Alfalfa fibre and soya fibre have shown promising results in terms of lactic acid yield when used as substrates[44].

3.6.1.3. Technologies and Production Process

Lactic acid can be produced through both chemical synthesis and fermentation methods. The chemical synthesis method, discovered in 1863, involves the lactonitrile route, where hydrogen cyanide is added to liquid acetaldehyde to create lactonitrile, which is then hydrolysed to produce lactic acid. Alternatively, lactic acid can be obtained via fermentation from biological feedstocks using bacteria, fungi, or yeast. Fermentation is particularly advantageous due to its reliance on renewable and cost-effective raw materials. After preparing the feedstock, processes like liquefaction, saccharification, and fermentation are followed by crucial downstream steps such as precipitation, solvent extraction, and membrane separation. These downstream processes, which represent 50% of production costs, are essential for recovering pure lactic acid, which is then used in industries like food, pharmaceuticals, textiles, cosmetics and chemicals[44].

3.6.1.4. Applications

Based on the search results, the key applications of lactic acid include:

- **Food industry:** Used as an acidifier, pH regulator, preservative, and flavouring agent in various fermented foods like yoghurt, bread, beer, cheese, and pickles.
- **Cosmetics and Personal Care industry:** Utilized as an emulsifier and moisturizer in cosmetic products, and with its moisturizing, exfoliating, and antibacterial properties, contributes to skincare products that provide a smooth complexion and prevent wrinkles.
- **Pharmaceutical industry:** used in the treatment of skin diseases, and gastrointestinal issues, and as a probiotic for digestive health.
- **Agriculture sector:** As fertilizers, lactic acid bacteria can promote biodegradation, accelerate soil organic content, and produce organic acid and bacteriocin metabolites that enhance plant health and growth
- **Chemical industry:** Lactic acid can be converted into various fuel compounds used in fuel production (i.e., 5-C 7ketones) and plastic production (PLA)[46].
- Serves as a **building block** for the synthesis of biodegradable polymers like polylactic acid (PLA), which are used in the production of eco-friendly materials (i.e., bioplastics, packaging…).

In summary, the diverse applications of lactic acid span the food, cosmetics, pharmaceutical, agricultural, and environmental sectors, highlighting its versatility and importance in sustainable production processes.

3.6.2. Succinic Acid

3.6.2.1. Product Description and Market Value

Succinic acid is a naturally occurring and versatile four-carbon dicarboxylic acid. In 2022, the global market value for succinic acid was estimated at USD 160.8 million, and it is expected to grow to USD 301.4 million by the end of 2032, with a projected compound annual growth rate (CAGR) of 6.5% from 2022 to 2032[47].

3.6.2.2. Biomass

Lignocellulosic feedstocks like *forestry residues* (wood and wood processing residues), agricultural residues, and energy crops are attractive renewable resources for cost-effective succinic acid production via fermentation after pretreatment and hydrolysis to release fermentable sugars. In particular, the most common agricultural residues and energy crops used to produce succinic acid include:

- Different types of **crop stalk wastes**, including corn stalk and cotton stalk, are commonly enzymatically converted into a carbohydrate-rich feedstock for succinic acid production[48].
- Different types of **crop straws,** including wheat straw, rice straw, barley straw, and corn straw are commonly used to produce succinic acid via fermentation. Also, miscanthus is a viable option.
- **Sugarcane Bagasse (SCB):** a viable alternative for the efficient production of succinic acid[49].
- Finally, the organic fraction of **Municipal Solid Waste (MSW),** particularly the lignocellulosic biomass, serves as a valuable feedstock for succinic acid production through innovative processes, showcasing the potential for sustainable and cost-effective bio-based chemical production[50].

3.6.2.3. Technologies and Production Process

The production of succinic acid involves several processes, the most relevant:

- **Enzymatic Hydrolysis:** use of enzymes to break down lignocellulosic biomass into simpler sugars, which are then fermented to produce succinic acid
- **Fermentation:** use of microorganisms to convert carbohydrates into succinic acid. This process involves the fermentation of sugars from hydrolysates by the microorganisms, which results in the production of succinic acid[51].
- More classic and well-known chemical methods, such as acid **Hydrolysis**, have not been considered because of their environmental impact.

3.6.2.4. Applications

Succinic acid is a valuable organic acid with high commercial value in the biobased market, and its applications include:

- **Chemical Industry:** used as a chemical intermediate in the production of various compounds, such as 1,4-butanediol (BDO), tetrahydrofuran (THF), and γ-butyrolactone (GBL, building block is the solvent market), which are further utilized in the manufacturing of polymers, resins, and polyurethanes. Succinic acid is a key component in the production of biodegradable plastics, polyesters, and polyamides, offering a sustainable alternative to traditional petrochemical-based materials.
- **Food and Beverage Industry:** used as an acidity regulator and flavouring agent, but also as a building block for biodegradable polymers used in food packaging.
- **Pharmaceuticals:** Succinic acid is employed in the pharmaceutical industry to produce active pharmaceutical ingredients (APIs) and as an excipient in drug formulations.
- **Cosmetic Industry:** It is utilized in the manufacturing of personal care products, such as skin creams, shampoos, and bath salts, due to its buffering and exfoliating properties. It can also be used in the production of biopolymers, solvents, plasticizers, and fine chemicals.

These applications demonstrate the versatility and potential of succinic acid as a renewable platform chemical with a wide range of uses across various industries[52].

3.6.3. Glycerol

3.6.3.1. Product Description and Market Value

Glycerol, also called glycerine or glycerine, is a chemical compound with three hydroxyl groups - which plays a crucial role in the biobased industry due to its versatile applications and renewable nature.
The global glycerol market was valued at $4.3 billion in 2021 and is projected to reach $5.1 billion by 2031, growing at a CAGR of 1.7% from 2022 to 2031[53].

3.6.3.2. Biomass

The production of glycerol involves the use of various vegetable oils and animal fats (transesterification and saponification). Some of the sources used for producing glycerol include:

- **Vegetable Oils:** Glycerol can be produced from vegetable oils such as canola oil, rapeseed oil, palm oil, and soybean oil.
- **Animal Fats:** Additionally, animal fats are also utilized in the production of glycerol. These animal fats can include waste cooking oil (WCO), non-edible oils, and other animal fat sources [54,55].

Glycerol is also generated as a by-product of sugar fermentation to ethanol. The most used sugar sources are:

- **Sugarcane and sugar beet**: major feedstocks for ethanol production, accounting for around 60% of global ethanol production
- **Corn (maize):** major starch-based feedstock used for ethanol production, especially in the United States. The starch is first hydrolysed to glucose before fermentation.
- **Molasses:** a byproduct of sugar production, and therefore a low-cost feedstock used for ethanol fermentation. It contains high levels of sucrose that can be readily fermented[56].

3.6.3.3. Technologies and Production Process

In the biobased industry, glycerol is primarily generated as a by-product of biodiesel production, where it is obtained from the transesterification reaction between triacylglycerols (e.g., vegetable oil) and methanol. Crude glycerol, containing impurities like alcohol, catalyst traces, esters, and salts, is a common form of glycerol produced in this process. To enhance its value and usability, crude glycerol can be purified to different purity levels required for various applications in foods, pharmaceuticals, and personal care products.
Glycerol is also produced as a by-product during soap production through saponification of glycerides. Glycerol and soap (fatty acid salts) are produced during the hydrolysis of oils and fats with alkaline hydroxides. This

process has been known since 2800 B.C., however, it is a process that can be environmentally impactful, as is a chemical process that involves chemical catalysts rather than biological organisms to facilitate the reaction.
Microbial fermentation has emerged as an interesting route for glycerol production, using osmo-tolerant yeasts like *Saccharomyces cerevisiae*, but also bacteria such as *Bacillus subtilis*, and algae like *Dunaliella tertiolecta*. The fermentation process utilizes biomass-derived sugars as feedstock, for example in *Saccharomyces cerevisiae*, glycerol is generated as a by-product of sugar fermentation to ethanol, following a redox-neutral pathway[57]. Despite this evidence, there are no recent studies concerning this process.

3.6.3.4. Applications

Glycerol, as a by-product of biodiesel production, is a renewable bio-derived feedstock that could be used as a source to obtain high-added products and fuels and thanks to its unique physical and chemical properties has a great number of applications.

- **Food Industry:** Added to food to increase water-coating ability, used as a sweetener, humectant, and solvent in foods and beverages
- **Pharmaceutical, Medical and Cosmetic Industry:** Used as a lubricant, humectant, and emollient in pharmaceutical formulations and personal care products (creams, cosmetics, soaps, balsams...), employed as a solvent, plasticizer, and sweetener in pharmaceuticals
- **Used less frequently in other industries:** in the manufacture of papers, wrapping and packaging materials (as a softener, humectant, and lubricant), in the textile industry (as a solvent, humectant, plasticizer, and lubricant), in the rubber industry (as a plasticizer, humectant, and lubricant), in the automotive industry (as an antifreeze) etc.

3.6.4. Polymers (PLA)

3.6.4.1. Product Description and Market Value

Polylactic acid (PLA) is widely acknowledged as a biodegradable and biobased polyester and has been extensively studied and is believed to be a promising substitute for petroleum-based polymers. This material has a wide range of applications across different industries, offering a more environmentally friendly alternative to conventional plastics. In particular, the PLA market was valued at $1.821 billion in 2022 and is projected to reach $5.186 billion, growing at a CAGR of 19.1% from 2022 to 2028 [58].

3.6.4.2. Biomass

The main biomass feedstocks used to produce polylactic acid (PLA) are:

- **Corn:** Corn starch is commonly fermented to produce lactic acid, which is then polymerized to make PLA. Corn is one of the most widely used feedstocks for PLA production.
- **Sugarcane:** Sugarcane is another major feedstock used to produce lactic acid for PLA synthesis. The sucrose from sugarcane is fermented to obtain lactic acid.
- **Cassava:** Cassava starch can also be used as a feedstock for PLA production. The starch is first converted to glucose, which is then fermented to lactic acid.
- **Wheat:** Wheat starch can also be used as a feedstock for PLA production. The starch is converted to glucose, which is then fermented to lactic acid.
- **Sugar Beet:** Sugar beet pulp, a byproduct of sugar production, has been explored as a feedstock for PLA. The cellulose in the pulp is hydrolysed to glucose, which is then fermented to lactic acid.
- **Lignocellulosic biomass:** Woody biomass like wood pellets has been investigated for PLA production. The cellulose and hemicellulose in the biomass are broken down into sugars that can be fermented to lactic acid[59].

3.6.4.3. Technologies and Production Process

The production of Polylactic acid (PLA) involves several key steps:

- **Fermentation of Lactic Acid:** Lactic acid, the precursor to PLA, is typically produced through fermentation of glucose or sucrose. This lactic acid is then purified to obtain polymer-grade lactic acid.

- **Condensation of Lactic Acid:** The polycondensation process involves concentrating lactic acid to remove residual water and producing an oligomer of limited molecular weight. This prepolymer is then thermally depolymerized to form lactide, the cyclic dimer of lactic acid, which needs to be of high purity for polymerization.
- **Polymerization:** This step utilizes a combination of a specially designed stirred-tank reactor and an efficient plug-flow reactor for ring-opening polymerization. This step is crucial for producing high-quality PLA with low residual monomer content
- **Stabilization and Demonomerisation:** The polymer melt is stabilized, and any remaining lactide is removed[60].

3.6.4.4. Applications

Polylactic acid (PLA) finds diverse applications across various industries due to its biocompatibility, biodegradability, and versatility. Some key applications of PLA include:

- **Medical Industry**: PLA is used in healthcare for tissue engineering scaffolds, bioabsorbable medical implants, drug delivery systems, and covering membranes in medical devices[61].
- **Food Packaging:** PLA is FDA-approved for food contact materials, making it suitable for containers, drinking cups, overwraps, and blister packages in the food industry.
- **Textile Industry:** PLA is utilized in textile fibre applications for shirts, carpets, bedding, mattresses, sportswear, and upholstery fabrics due to its low moisture absorption and UV resistance.
- **3D Printing:** PLA is a popular filament for fused deposition modelling (FDM) in 3D printing due to its low melt temperature and ease of use.
- **Automotive and Structural Applications:** PLA and PLA composites are used in automotive, electrical, and electronics applications for parts like floor mats, safety helmets, pillar covers, and interior components of automobiles[62].

These applications highlight the versatility and eco-friendly nature of PLA, making it a valuable material in modern industries ranging from healthcare to textiles and beyond.

3.6.5. Amino acids (Lysine)

3.6.5.1. Product Description and Market Value

Lysine is an essential amino acid crucial for various human bodily functions, but it is also a crucial component in the biobased industry, particularly in the production of various chemicals and materials. Its unique chemical structure and sustainability make it an attractive raw material for industrial applications. According to the latest market research reports, the global lysine market is expected to reach significant market value in the coming years. It was valued at USD 1,754.9 million in 2021 and is projected to grow at a CAGR of 7.5% from 2022 to 2030[63].

3.6.5.2. Biomass

The biomass feedstocks commonly used to produce lysine include:

- **Sugars:** Raw materials for microbial fermentation processes derived from lignocellulosic biomass require pretreatment and hydrolysis to release fermentable sugars, converted to lysine by engineered microbial strains. Lignocellulosic biomass commonly used to produce lysine includes corn stubble and wheat straw.
- **Starches**: Starch from food crops is another common feedstock for lysine production. However, there is a growing interest in replacing food-crop starch with lignocellulosic materials to avoid competition with food supply.
- **Hemicellulose:** Hemicellulose, a component of lignocellulosic biomass, can be hydrolysed into fermentable sugars. These sugars can be utilized by certain strains capable of fermenting pentose sugars, which are derived from hemicellulose, for lysine production.

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- **Molasses** is indeed used in the production of lysine. It serves as a carbon source in the fermentation process for lysine production, offering a sustainable alternative to traditional glucose sources. Research has shown that molasses can effectively replace glucose in lysine production, reducing production costs and using this by-product from the sugar industry[64].

3.6.5.3. Technologies and Production Process

The technologies used to produce lysine from biomass include microbial fermentation, a key method for producing lysine from renewable sources like lignocellulose, starches, and/or hemicellulose. This process involves using microorganisms to convert biomass-derived sugars into lysine through fermentation[65]. The key steps involve:

- Pretreatment and **hydrolysis** of the biomass to break down the complex structure and release fermentable sugars like glucose and xylose.
- **Fermentation** of the biomass-derived sugars using engineered microorganisms to convert them into lysine.
- **Downstream** processing to purify and recover the produced lysine from the fermentation broth. The conversion of xylose, a pentose sugar present in lignocellulose, remains a challenge in lysine production from biomass. Ongoing research focuses on improving lysine-producing strains' ability to efficiently utilise hexose and pentose sugars derived from lignocellulosic feedstocks[65].

3.6.5.4. Applications

Lysine has numerous industrial applications:

- **Animal Feed Industry:** Lysine is a major additive to animal feed (NACE: 10.9). It is a limiting amino acid that promotes growth. Adding lysine allows using lower-cost plant proteins while maintaining high growth rates. The global lysine market for animal feed was valued at $8.6 billion in 2023 and is expected to grow at a CAGR of 7.2% from 2024 to 2033.
- **Food and Beverages Industry:** L-lysine is a nutritional supplement for mayonnaise, milk, instant noodles, potatoes, rice, flour, and canned foods. It can also enhance flavour. Lysine is also used in nutritional and sports drinks (NACE: 10, 11).
- **Pharmaceutical Industry:** Lysine is used in the production of various medicines (NACE: 21).
- **Cosmetics and Personal Care Industry:** Lysine is used in cosmetics and personal care products, such as baby products, bath products, cleansers, eye makeup, shaving preparations, and hair and skin care (NACE: 20.4). It helps with skin elasticity and firmness due to its role in collagen synthesis[66].

In summary, lysine has a wide range of industrial applications. The largest demand comes from the animal feed sector, followed by food, pharmaceuticals, and cosmetics. Ongoing research aims to improve the efficiency of lysine production and expand its use as a versatile industrial compound.

3.7. SAT User Interface

The SAT user interface is currently designed as an Excel matrix with **6** sheets.
The **first sheet** serves as an introduction, offering a concise overview of the SAT, guidance on its usage, and instructions on how to interpret the results effectively. **Subsequent sheets** are dedicated to detailed analyses for each biobased final product—*PLA, Lactic Acid, Glycerol, Succinic Acid, and Lysine*—along with their respective value chains. Each of these sheets provides tailored insights and tools for users to assess and compare the performance and sustainability of these key biobased products in the Alpine context.

The design of the SAT interface emphasizes **user-friendliness** and **accessibility**, ensuring that even those with limited technical expertise can navigate and utilize the tool effectively. Each analysis sheet is structured to allow users to input specific data, compare it against the established benchmarks, and visualize the results through intuitive **graphs** and **charts**. Additionally, the interface includes automated features that simplify data entry and analysis, reducing the potential for user error and enhancing the reliability of the outcomes. This structured yet flexible approach makes the SAT a powerful tool for decision-making, enabling stakeholders to identify opportunities for improvement, optimize production processes, and ultimately contribute to a more sustainable biobased economy in the Alpine region.

In Fig. 5, a facsimile of the user interface is presented. The analysis sheets within the interface are uniformly structured, beginning with a table where the testing company can input data related to the 6/7 pre-selected sustainability criteria. This input data is then compared to fixed benchmark values representing sustainable practices, enabling the company to assess its social, economic, and environmental sustainability concerning these goals. The SAT further facilitates the identification of **sustainability hotspots**—areas where the company's performance falls short of the benchmark—by employing a colour-coded system for clarity.

In the "maximisation" evaluation type, which represents the criteria in which the higher the value the better the overall sustainability:

- **Green**: values with a score greater than 80% of the benchmark value
- **Yellow**: values lesser than 79% and greater than 45% of the benchmark value
- **Red**: value lesser than 44% of the benchmark value

For the "minimization" evaluation type, which represents the criteria in which the lower the value the better the overall sustainability:

- **Red**: values with a score greater than the benchmark value
- **Green**: value lesser or equal to the benchmark value

Additionally, the tool offers graphical representations for each category, visually highlighting hotspots where the company's data significantly diverges from the benchmarks, signalling areas in need of improved management.

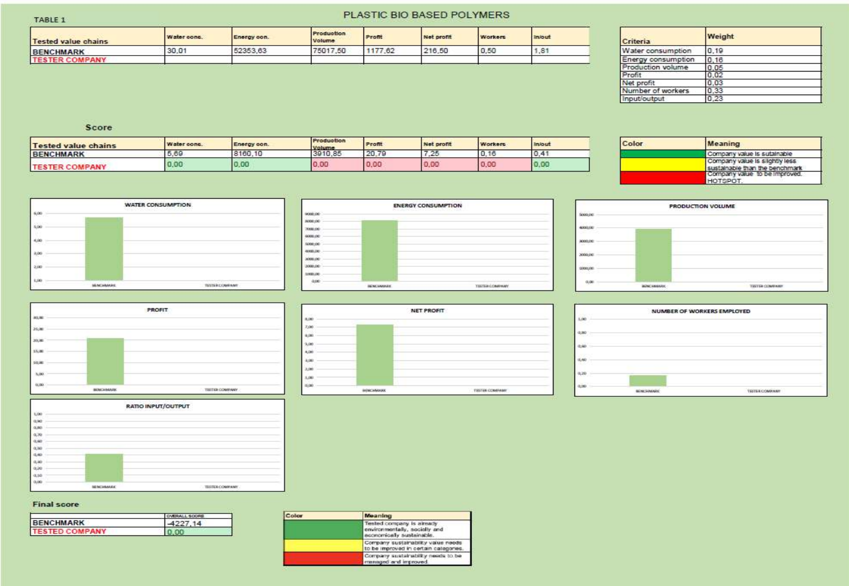


***Figure 5:** SAT user interface*

4. Technical Benefits of the SAT for the Companies

The Sustainable Assessment Tool (SAT) offers a range of technical benefits that are fundamental for companies aiming to enhance their sustainability practices. One of the core advantages is its ability to provide a comprehensive **evaluation of sustainability across environmental, social, and economic dimensions**. This holistic approach ensures that companies gain a deep and nuanced understanding of their sustainability performance, allowing them to address all factors of their impact.

Another key feature of the SAT is its **benchmarking capability**. By comparing a company's performance against established industry benchmarks, the tool helps identify gaps, inefficiencies, and areas ripe for improvement. This comparative analysis is instrumental in guiding companies toward adopting industry best practices, enabling them to enhance their sustainability efforts and strategically address hotspots within their processes or products.

Moreover, the SAT supports **strategic decision-making** through its Multi-Criteria Decision-Making Analysis (MCDMA). This feature allows companies to evaluate various sustainability factors in a structured manner, providing visual representations and an overall performance score. With this data-driven insight, companies can make informed decisions that optimise sustainability throughout their entire value chain. The SAT not only aids in regulatory compliance and risk management but also drives innovation by highlighting opportunities for integrating cutting-edge technologies and practices. Ultimately, this tool helps companies in their sustainable development, improving their reputation and competitive advantage within their industry.

5. SAT integration with IEC24 and VCG.AI

The Sustainable Assessment Tool (SAT) was specifically designed to keep in mind the objectives of the **Innovation Express Call 24 (IEC24)** a joint call for proposals implemented by synchronizing existing regional funding schemes in the Alpine Space and beyond. This Alpine space call targets biobased companies seeking to implement and enhance their business models. To maximize its utility for potential applicants, the SAT has been integrated into the project's webpage starting from March 2024 (https://www.iec24.info/tools.html), complete with a comprehensive **explanatory PDF** outlining its functionality.

Additionally, a decision-flow diagram (Fig.6) has been provided to guide users through the process, ensuring they can effectively exploit the tool to meet their sustainability goals and choose to use the SAT in addition to the **VCG.AI**, an artificial intelligence tool that allows creating a sustainable value chain from zero.

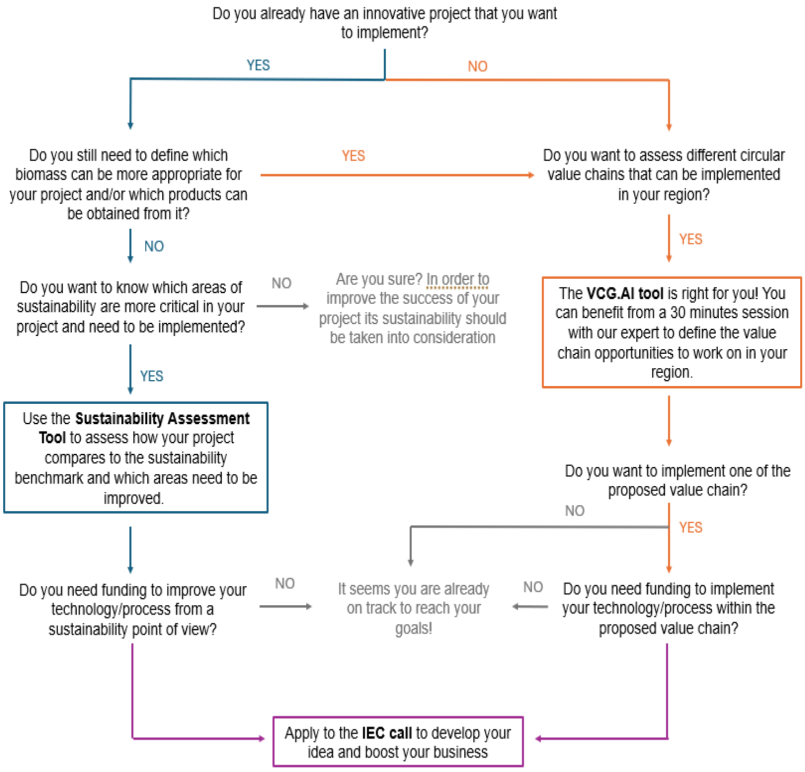


***Figure 6:** SAT decision Flow*

6. SAT dissemination

The dissemination activities surrounding the Sustainable Assessment Tool (SAT) have been strategically designed to **maximize outreach and engagement** with relevant stakeholders, ensuring widespread awareness and understanding of the tool's utility in promoting sustainability practices. Central to our dissemination strategy has been the use of **multiple communication channels**, including LinkedIn posts, newsletters, and the creation of a promotional video. These efforts have been coordinated to build a cohesive narrative around SAT, emphasizing its value proposition and impact on sustainable practices across various sectors.

Our LinkedIn posts have been fundamental in reaching a professional audience, particularly those involved in sustainability, environmental management, corporate responsibility, and related fields. The posts have been carefully crafted to highlight different aspects of the SAT, such as its key features and benefits for organizations looking to improve their sustainability performance.

By leveraging **LGCA** LinkedIn's extensive network, we have been able to target industry professionals and decision-makers who are likely to benefit from or advocate for the adoption of the SAT. Additionally, we have utilized LinkedIn's analytics to monitor the performance of our posts, allowing us to refine our content strategy to better resonate with our audience.
The last LGCA SAT post on LinkedIn performed well, garnering a total of **463** impressions. It attracted 19 clicks, indicating strong interest from our audience. Additionally, the post received 8 reactions, demonstrating positive engagement, and was shared 3 times, which helped to further extend its reach. These metrics reflect a solid level of interaction and visibility within our network.

Complementing our LinkedIn strategy is the dissemination with **newsletters**, which serve as a direct communication channel with a targeted list of subscribers, including current and potential users of the SAT, partners, and stakeholders both from the LGCA network and INNOBioVC partnerships. The newsletters are designed to be informative and visually engaging, providing insights into the SAT's functionalities and updates on new features, ensuring that our audience remains actively engaged with the SAT. The effectiveness of our newsletters is regularly assessed through metrics such as open rates, click-through rates, and subscriber feedback, which are used to continually improve our communication strategy. In particular, the latest LGCA newsletter on SAT was successfully delivered to 935 recipients out of 946, achieving an impressive open rate of 42.5%. Notably, 20 recipients (2.1%) clicked on links within the email, with 11 clicks directed specifically to the https://www.iec24.info/tools.html page.

Another key component of our SAT dissemination efforts is the production and distribution of a **promotional video** that showcases the SAT's utility and impact within the IEC24 call (Fig.7). The

***Figure 7**: INNOBIOVC video frame on SAT*

video has been designed to be concise yet informative, combining engaging visuals with clear, straightforward messaging to convey the essence of the SAT in a way that is accessible to a broad audience. To maximize its reach, the video has been optimized for different formats, ensuring compatibility across various devices and platforms.

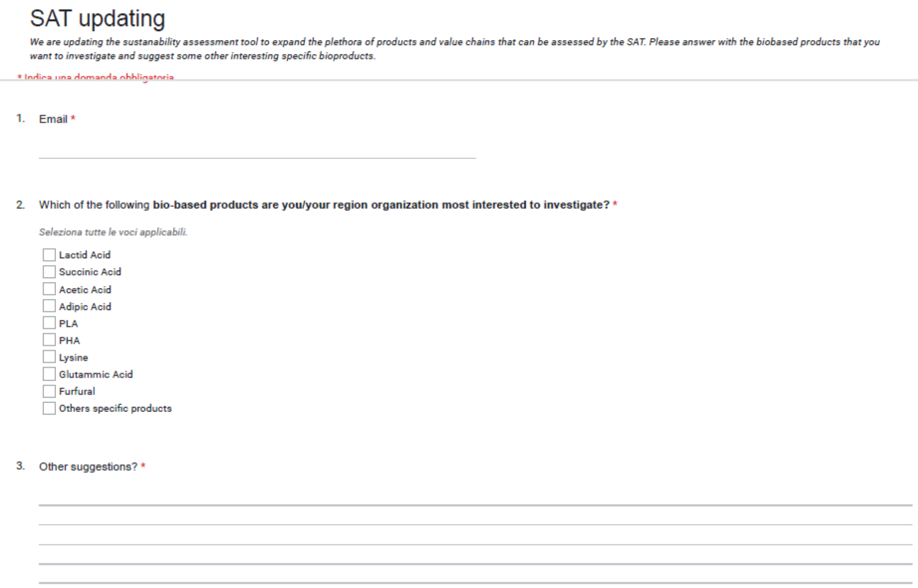
These dissemination activities are part of a broader, **integrated communication strategy** aimed at establishing the SAT as a go-to tool for sustainability assessment across industries. By leveraging LinkedIn posts, newsletters, and video content, we have created multiple touchpoints for our target audience, ensuring that the message about the SAT's utility is both pervasive and persuasive. Each activity is carefully planned and executed to reinforce the others, creating a consistent and compelling narrative around the SAT. Furthermore, we have prioritized feedback and engagement, using insights from our audience to continuously refine our dissemination tactics and improve the relevance and impact of our communications. This approach ensures that our messaging remains aligned with the evolving needs and interests of our audience, ultimately driving higher levels of adoption and utilization of the SAT.

7. SAT Challenges and Limitations

The development and deployment of the Sustainable Assessment Tool (SAT) within the framework of the IEC24 call were intended to provide a structured and reliable means of evaluating sustainability initiatives, particularly those focusing on the utilization of agricultural and industrial residues. The SAT was designed to offer call applicants a **standardized approach** to assess and increase the environmental, economic, and social impacts of their proposed projects. However, it is evident that many products, especially innovative ones, were not included. Upon closer analysis and feedback from the few applicants, it became apparent that this outcome was likely influenced by call context-specific issues that were not fully anticipated during the initial development of the tool.

8. SAT Updating

To solve the mismatch issue, we initiated a comprehensive **review process**, which included the distribution of a questionnaire (Fig.8) to our key stakeholders and project partners.


SAT updating

We are updating the sustainability assessment tool to expand the plethora of products and value chains that can be assessed by the SAT. Please answer with the biobased products that you want to investigate and suggest some other interesting specific bioproducts.

* Indica una domanda obbligatoria

1. Email *

2. Which of the following **bio-based products** are you/your region organization most interested to investigate? *

Seleziona tutte le voci applicabili.

- Lactid Acid
- Succinic Acid
- Acetic Acid
- Adipic Acid
- PLA
- PHA
- Lysine
- Glutammic Acid
- Furfural
- Others specific products

3. Other suggestions? *

***Figure 8**: SAT updating questionnaire*

The goal of this questionnaire was to gather insights into the specific products and value chains that were most relevant to the current landscape of sustainable development initiatives. By engaging directly with those who were actively involved in the field, we aimed to better understand the evolving priorities and challenges enabling us to **refine** the SAT in a way that would maximize its utility and impact.

The questionnaire was short and designed in a way that respondents were asked to provide feedback on the types of residues they were most interested in working with, and the specific products they believed held the greatest potential for sustainability gains within the IEC24 call.

One of the key findings was that there was significant interest in products derived from a wider variety of residues than initially anticipated. For example, while the original SAT focused on the 5 main economically valuable biobased products, the feedback indicated a growing interest in residues from more niche sources, such as **biochar** from forestry operations, and industrial by-products like **Bioethanol** and **Acetic acid**. This shift in focus reflects broader trends in the sustainability field, where there is increasing recognition of the potential to valorise a diverse array of waste streams that were previously underutilized.

In response to these findings, we undertook a targeted effort to **expand the SAT's** product offerings to better align with the needs and interests of the stakeholders. Specifically, the previous 3 new products were added to the tool, each representing a different type of residue that had been highlighted as a priority by the questionnaire respondents. The first of these new products focuses on **biochar**, a carbon-rich material that can be produced from a variety of biomass residues and is increasingly being recognized for its potential to improve soil health, sequester carbon, and reduce greenhouse gas emissions. The second product centres on the use of **bioethanol** a renewable fuel made from fermenting plant materials, offering a sustainable alternative to fossil fuels and reducing greenhouse gas emissions in transportation. The third product involves **acetic acid**, a key industrial chemical used in the production of various products such as plastics, textiles, and food additives, forming a crucial link in the value chain of sectors like pharmaceuticals, food preservation, and synthetic materials.

Each of these new products was integrated into the SAT by July 2024, with corresponding benchmark configurations that reflect the unique characteristics and challenges associated with each residue type. In addition to expanding the range of products and value chains covered by the SAT, we also took the opportunity to refine the tool's underlying assessment framework.

8.1. SAT User interface updates

Another important aspect of the update process was the incorporation of feedback on the usability and accessibility of the SAT. Several respondents to the questionnaire highlighted the need for a **more user-friendly interface**, as well as the importance of providing clear guidance on how to navigate the tool and interpret its results. In response, we made several enhancements to the SAT's interface, including the addition of **step-by-step tutorials, interactive help features,** and more intuitive navigation options. These changes were designed to make the tool more accessible to a wider audience, including those who may not have extensive experience with sustainability assessments but are nonetheless interested in incorporating sustainability principles into their projects.

The updated SAT has since been re-released to the stakeholder community, early feedback from our LGCA network has been positive, with users expressing appreciation for the expanded product offerings and the improved usability of the tool. Several participants also noted that the new product range provided by the SAT was particularly **helpful** in guiding their project planning and decision-making processes, as they offered clear and actionable insights into the potential sustainability impacts of different residue utilization strategies.

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9. Conclusions and Next Steps

In conclusion, the experience of developing and refining the Sustainable Assessment Tool (SAT) for the IEC24 call has accentuated the importance of context-specific considerations in creating effective sustainability assessment tools. Engaging with a diverse range of stakeholders was crucial in updating the original SAT. Their feedback allowed us to create a more comprehensive and user-friendly tool that better meets the needs of the sustainability community. This process also highlighted the importance of flexibility and adaptability in sustainability tools. By incorporating a **modular approach**, the SAT can be continuously improved without compromising its core functionality.

Moreover, the refined SAT emphasises a holistic approach by integrating social, environmental, and economic dimensions, offering a more complete assessment of sustainability initiatives. This multidimensional perspective is vital for understanding and addressing the complex nature of sustainability challenges.

Next steps

Moving forward, our strategic priorities will include deepening our **engagement with stakeholders** and project partners to ensure that the SAT remains a relevant and effective tool for advancing sustainable development initiatives. As the sustainability landscape continues to evolve, the SAT must adapt to these changes. To this end, we will implement ongoing monitoring mechanisms to track the tool's usage and assess its impact. These insights will permit periodic updates that will incorporate new products, value chains, and cutting-edge assessment methodologies, ensuring the SAT stays aligned with emerging trends and best practices.

Moreover, recognizing the diverse needs of our global user base, we are actively exploring opportunities to expand the SAT's reach. This includes **translating the tool into multiple languages** and **adapting it to various regional contexts**. By making the SAT more accessible to a broader audience, we aim to empower a wider range of users to leverage its capabilities, thereby maximizing its contribution to sustainable development.

In addition to these efforts, we are committed to **enhancing the integration of the SAT within the VCG.AI tool**. This integration will not only streamline workflows but also create a more cohesive user experience. Our goal is to transition from the current Excel-based format to a more sophisticated, **user-friendly interface** that allows for more seamless data entry, analysis, and reporting. By doing so, we will enable users to navigate the tool more efficiently, ultimately leading to more informed decision-making and greater impact in sustainability efforts.

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Annexe

Communication material

LinkedIn Post on SAT

🎉 Introducing the Sustainability Assessment Tool (SAT) by INNOBIOVC! 🌱
We are thrilled to present our cutting-edge Sustainability Assessment Tool (SAT) developed within the INNOBIOVC project. This powerful tool is designed to help companies evaluate and enhance the sustainability of their bio-based processes or products, covering environmental, social, and economic dimensions.
🔍 Key Features:
- Comprehensive Evaluation: Holistic assessment of sustainability performance.
- Benchmarking for Improvement: Identify areas for improvement by comparing with industry benchmarks.
- Available value chains: targeting bio-based products such as lactic acid, succinic acid, glycerol, polymers (mainly PLA), and amino acids (mainly lysine and glutamate).

Ready to take your sustainability efforts to the next level? Explore the SAT and discover how you can make your processes more sustainable!
🔗 Learn more about SAT
#Sustainability #BioBasedProducts #Innovation #SustainableDevelopment #INNOBIOVC

(link to the webpage https://www.iec24.info/tools.html)

Newsletter Text

Enhance Your Sustainability with the New Sustainability Assessment Tool (SAT)
Dear [Recipient's Name],
We are excited to introduce the Sustainability Assessment Tool (SAT), an innovative solution developed within the INNOBIOVC project, designed to help companies achieve greater sustainability in bio-based processes or products. The SAT offers a comprehensive assessment across environmental, social, and economic dimensions, providing a clear path to improve your sustainability performance.

Why Choose SAT?
1. Comprehensive Sustainability Evaluation: The SAT offers a thorough assessment, covering all three dimensions of sustainability—environmental, social, and economic. This ensures a holistic

This project is co-funded by the European Union through the Interreg Alpine Space programme

understanding of your product or process's impact.
2. Benchmarking for Improvement: By comparing your innovative product or process with established benchmarks, the SAT helps identify key areas for improvement. This feature enables you to adopt industry best practices and address hotspots in your value chain.
3. Strategic Decision-Making: Utilizing Multi-Criteria Decision-Making Analysis (MCDMA), the SAT provides structured and informed decision-making support. With visual representations and an overall performance score, you can strategically enhance your sustainability efforts.

The SAT is currently tailored for value chains targeting bio-based products such as:
- Lactic acid
- Succinic acid
- Glycerol
- Polymers (mainly PLA)
- Amino acids (mainly lysine and glutamate)

We also offer a comprehensive set of resources to support your use of the SAT, including an Excel file for calculations, a detailed PDF guide, and a reference file for benchmark products. Our team at LGCA is available for any support you may need.
Ready to start your sustainability journey with the SAT? Visit our website to learn more and get started.
For any questions or support, please feel free to reach out to us at federica.binello@italbiotec.it

Best regards,

(link to the webpage https://www.iec24.info/tools.html)

Benchmark data

SHARE OF FEMALES

- https://www.researchgate.net/publication/278044971_Guest_Editorial_The_Professional_Status_of_European_Chemists_and_Chemical_Engineers
- https://www.forbes.com/sites/sap/2023/08/22/women-in-the-chemical-industry-were-at-a-groundbreaking-leadership-moment

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