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ENVIRONMENTAL TECHNOLOGY VERIFICATION (ETV): A TOOL TO DEMONSTRATE THE INNOVATIVENESS OF TECHNOLOGICAL SOLUTIONS FOR CIRCULAR TRANSITION

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Abstract

The Environmental Technology Verification (ETV) tool is part of a voluntary programme to facilitate market access for new environmental technologies. It is a verification protocol for innovative technologies based on their environmental performance, impartially certified by an accredited verification body. As part of the LIFEproETV project, an European initiative aimed at promoting market acceptance and recognition of the ETV scheme, ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) has identified ETV as a key instrument to support innovation in the field of Circular Economy (CE). Indeed, the transition towards circular production and consumption models implies the use and dissemination of new technologies, whose environmental performance must be credible and impartially verified.
The ETV scheme has been successfully applied to verify the performance of 15 innovative environmental solutions with circular applications. These technologies could not be measured or verified using existing regulations, certifications, authorizations, or standards.
In this context, to identify concrete use cases for ETV within Italy's environmental policies and to outline the opportunities and enabling environment for promoting ETV-verified technologies that support the circular economy, ENEA has developed a roadmap. This roadmap defines the potential areas where ETV can be used as a policy tool to help achieve the specific objectives of the National Strategy for the Circular Economy (NSCE). It also explores the value and potential benefits of using the ETV scheme to foster innovation ecosystems, address environmental challenges, and promote sustainable finance.
Key words: circular economy, EN ISO 14034, environmental technologies, industrial symbiosis, green performances

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1. Introduction

The Environmental Technology Verification (ETV) scheme has been conceived with aim of facilitating the demonstration of the environmental performance of new technologies and accelerating their market adoption, as investigated by Merkourakis et al. (2007). Based on internationally recognised verification procedures included in EN ISO 14034 (Environmental Management - ETV and competences confirmed by national accreditation bodies through accreditation for compliance with ISO 17020) for Type A inspection bodies, verification bodies provide objective evidence that the claimed environmental performance of technologies is valid and supported by quality assured test data, as recently outlined by Hansen et al. (2021).

ETV can operate either as an independent market mechanism or as part of a broader program to support the implementation of environmental policies. In this regard, the European Commission has established and promoted a dedicated EU ETV programme for several years (COM, 2008).

A pilot phase of the Environmental Technology Verification (ETV) programme was launched in 2012 to investigate three key technology

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areas: water treatment and monitoring, energy technologies, and materials, waste and resources. In addition, in view of the expansion of the EU ETV programme from pilot to full scale initiative, four additional technology areas were defined: cleaner production and processes, air pollution control and monitoring, soil and groundwater remediation technologies, and environmental technologies for agriculture. However, the European Commission decided to discontinue its support for the EU ETV programme as of November 2022, following an internal evaluation.

Despite this decision, there remains a strong and ongoing demand among stakeholders for impartial, verified data on environmental technologies. LIFEproETV project aims to fill this gap by promoting and establishing a voluntary scheme to verify the performance of new environmental technologies prior to market entry. In consequence of the closure of EU ETV programme, verification bodies and other entities involved will need to develop a market-driven business model to continue their activities in compliance with ISO 14034. This will require the formation of new partnerships between ETV bodies in Europe and market players. These stakeholders will need to clearly define their roles within the value chains to which they contribute, aligning their capabilities with the specific needs of the industries they serve. Notwithstanding these challenges, the role of ETV in providing objective, credible information on green alternatives remains vital. There is significant potential for ETV to be supported by both market and policy actors moving forward.

In accordance with the Policy Brief published within the LIFEproETV project, the information provided by ETV can also serve as evidence for revision of performance-based regulations for meeting the targets defined in EU Green Deal policies (LIFEproETV, 2022).

1.1. ETV supporting CE: current state

The concept of CE represents a cross-cutting theme that encompasses a wide range of issues including the reduction and optimisation of raw materials, the reuse of products, the strengthening of secondary materials value chains, w and eco-design. The overarching objective of CE is to facilitate the transition towards more sustainable production and consumption models, focusing both on environmental and economic sustainability. By promoting and reinforcing new business models that lead to significant material savings throughout the value chain and by fostering IS collaborations, the CE create valuable business opportunities. Innovative environmental technologies, products and services are key enablers of these processes (Chertow, 2000). The lack of credible, high-quality information on the performance and outcomes of new environmental technologies often hinders their implementation and hampers the purchasing decisions of final technology buyers. In this context, ETV has a great potential to meet this need also investigated by Marrucci et al. (2019), detailed study has been conducted to identify technologies that have already been validated through ETV and are directly related to circular economy applications or support the transition towards circular models. An in-depth analysis, conducted as part of the 'Roadmap for building ETV market acceptance and recognition' (LIFEproETV, 2023b), examined technologies with verified environmental performance. Of the 60 technologies verified by ETV, 25% are linked to the circular economy (CE). These are mainly in the technology areas of materials, waste and resources (80%), water treatment and monitoring (13%) and energy technologies (7%), as illustrated in

Fig. **1**. The ETV scheme has been successfully used to provide independent, credible and market-relevant information on 15 innovative environmental solutions, listed in Table 1. These solutions have applications in the circular economy, including:

- New technical solutions for waste separation and recycling, energy and resource recovery from waste and water recycling;
- New materials such as bio-based and biodegradable plastics.

As they fall outside the existing regulatory, certification, approval or standards frameworks, their performance characteristics could not otherwise be accurately measured and verified (LIFEproETV, 2024).

1.2. ETV in support of the Italian strategy to guide the transition to the CE

In Italy, nine technologies have been verified through the ETV scheme, all of which are provided by Italian technology providers. These technologies have been validated by two Italian verification bodies, RINA and Certiquality, which together have certified a total of 11 technologies under the ETV scheme, in particular in the field of water treatment and monitoring.

The interest in adopting this tool is evident from the number of Italian technologies verified with ETV, but there are several barriers to its diffusion and adoption. Despite these challenges, the NSCE emphasizes the need to incorporate criteria for assessing and quantifying the innovativeness of technologies, which is critical for advancing the CE. Specifically, the NSCE stresses the importance of defining clear indicators and parameters that can be used to monitor economic circularity and ensure the efficient utilization of resources. By integrating ETV into these frameworks, Italy can better facilitate the transition to a CE and encourage the adoption of innovative technologies that support sustainability goals. The Italian National Strategy for the Circular Economy (MITE, 2022) is a programmatic document launched in June 2022. Its purpose is to establish the framework of institutional policies needed to guide Italy's transition toward circular models of growth and development.

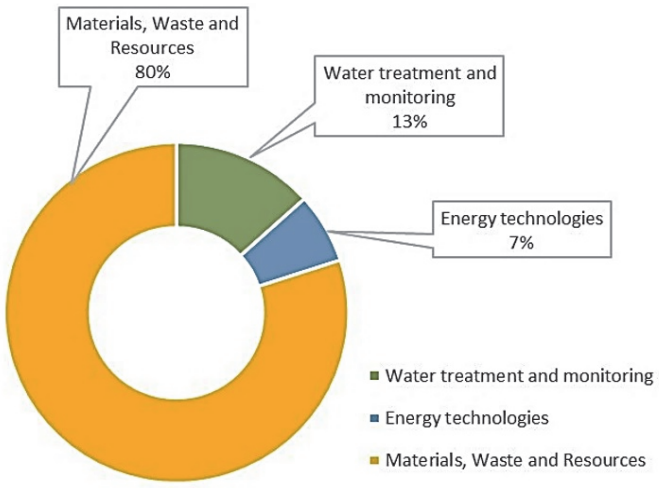

Fig. 1 . Detail of the technological areas of belonging for technologies verified with ETV in circular applications

Table 1. ETV verified technologies for CE applications

Technology name	***Technology function***	***Producer/Provider***	***ETV Statements of Verification no:***
RECYOUEST process	Recycling of contaminated plastics from agricultural environment	Recyouest, France	VN20190036
BIO-COM SYSTEM	Biostabilisation and composting of organic waste	SELMA Sp. z o.o., Poland	VN20150005
ECOGI	Separator for extraction of organic waste from pre-sorted household waste	Komtek Miljø A/S, Denmark	VN20160011
EWA Aerobic Fermenter, model 2020	Aerobic stabilisation of organic waste and sanitation of animal by-products	RSP Ostrava, a.s., Czech Republic	VN20160014
PURROT	Separation of dry matter from liquid waste	PurFil Aps, Denmark	VN20150006
ReStoRe	Transformation of low-value spent refractory waste into high-value products for steelmaking	Deref S.p.A, Italy	VN20210048
BIOMInE® BM-LMI-03	Biobased (80% organic carbon) polymer from PLA	Futuramat, France	VN20170020
BIOPOLYME BP-LXX-06	Biobased (81% organic carbon) polymer from PLA and starch	Futuramat, France	VN20170019
Re-Match Artificial Turf Recycling	Recycling of synthetic turf	Re-Match, Denmark	VN20170025
LIGNO-ENZYM	Enzyme decomposition of organic waste to intensify methane production in biogas plants	CONFORMITY, s.r.o., Czech Republic	VN21210045
Periodic anaerobic bioreactor ANABIOREC	Enhance the energy recovery from separated organic fraction of municipal waste	NOVAGO Sp. z o.o., Poland	VN20190037
Rich Water series 2018	Wastewater treatment for combined irrigation and fertilisation purposes	BIOAZUL S.L., Spain	VN20200042
HYDRO-1	Reclamation of water and nutrients from wastewater for agriculture applications	IRIDRA Srl, Italy	VN20220054
MATER-BI	Biodegradable and compostable bioplastics mainly made from renewable materials	Novamont S.p.A., Italy	VN20150004
Biofibra®	Biodegradable biopolymers made entirely of bio-based carbon materials	FuturaMat, France	BF-LhE-01 – VN20160013 BF-LED-10 – VN20160021

The strategy outlines the specific actions, objectives, and measures that will be promoted to achieve this transition.

Italy began exploring the concept of the circular economy as early as 2017, initiating a series of consultations with a diverse range of stakeholders, including businesses, industry representatives, and consumers. These consultations were aimed at defining the goals and measures necessary to position Italy as a leader in this. This was done in alignment

with the commitments made within the Paris Agreement on climate change, the United Nations 2030 Agenda on sustainable development, the G7, and the European Union (LIFEproETV, 2023b).

The NSCE incorporates contributions from both throughout the 2017 and 2021 +consultation phases. Its goal is to outline a comprehensive action plan encompassing the strategic directions and measures that must be undertaken to initiate a transition towards innovative, circular economic models. The strategy focuses on the following key themes: eco-design; reuse and repair; end-of-life (EoW); critical raw materials and the development of a secondary raw materials market; Green Public Procurement (GPP) and Minimum Environmental Criteria (MEC); strategic industrial supply chains; IS; Extended Producer Responsibility (EPR); digitisation; and tools to support CE.

While Italy faces challenges in decoupling economic growth from resource consumption, there are positive signs regarding its circular material use. In 2021, Italy's rate of circular use of materials stood at 18.4%, well above the European average of 11.7%, according to Eurostat and the Circular Economy Network (CEN) (CEN, 2023). This marks a significant improvement from previous years, positioning Italy among the leading countries in advancing the CE. Nevertheless, there is a call for both Italy and Europe to expedite their transition towards circular models in order to address environmental and geopolitical challenges. This is crucial in maintaining a pivotal position within the international and European landscape, while also guaranteeing the attainment of progressive improvement objectives.

Innovative environmental technologies, products and services are enabling factors in these processes. However, the lack of reliable, high-quality information on their performance and outcomes often impedes their adoption. Without such information, technology users and buyers are unable to make informed purchasing decisions.

2. Material and methods

The methodology proposed in this study has been developed to create a roadmap to facilitate the development of market acceptance and recognition of ETV as a voluntary environmental scheme. The aim to accelarate the uptake of new environmental technologies in the market. The methodology presented in this study can be used by a wide range of stakeholders to propose a framework for valorizing new environmental technologies in the market, addressing real use cases and challenges, and leveraging the benefits of ETV.

Technology producers and developers can apply this methodology to highlight the environmental benefits of the technologies they develop, specifically within the context of particular environmental, policy, or regulatory challenges. This approach enhances the competitiveness, credibility, and innovative potential of these technologies, making them more attractive to the market. The methodology is also valuable for potential investors or users, as it provides a clear understanding of the economic and environmental benefits, enabling more informed and responsive decision-making when selecting innovative solutions. Additionally, policymakers can use the methodology to develop strategic innovation pathways, guiding the creation of supportive frameworks for sustainable technology adoption.

In accordance with this approach, five national roadmaps were devised (one for each country: Hungary, Italy, Poland, Slovenia and Spain), delineating explicit objectives for the campaigns and substantiating the business case for ETV. The roadmaps demonstrated the distinctive value proposition of ETV in relation to national or European policies, fostering national or sectoral innovation ecosystems, addressing environmental challenges, and supporting sustainable financing. While the contexts of ETV market acceptance and recognition vary across the aforementioned countries, the ETV use cases and methodology for the development of roadmaps can serve as a source of guidance for other countries, decision-makers, and organisations interested in applying the ETV scheme for their own purposes.

This document outlines a methodology developed as a structured process comprising distinct phases (steps). Each phase is investigated in depth, with a particular focus on defining the individual elements that emerge according to a systematic framework. Fig. **2** provides a general overview of the methodology, highlighting illustrating the aspects addressed in each phase and the unique elements characterizing each step. The phases can be summarised as follow:

- Step 1: *ETV use case definition*

The main users of ETV are identified and the methods for applying ETV to achieve specific objectives are outlined. Partners of the LIFEproETV Project formulated hypotheses regarding the potential use cases. Following consultation with the main stakeholders, the use case was validated on the basis of positive feedback.

- Step 2: *Problem definition*

Provides a comprehensive description of the issues, conditions and challenges related to the use case. It identifies discrepancies between the problem and the objective, focuses attention on factors impeding application, defines stakeholders and establishes priorities.

- *Step 3: Action plan*

A checklist is created to outline the steps needed to achieve set goals. The action plan is the main part of the strategic planning process. In this phase, the actions, subjects, priorities and timing are defined.

With regard to the Italian Roadmap, ENEA focused its attention on the subject of the circular economy, with a view to achieving the specific objectives set out in the national policy. The NSCE constitutes a substantial advance in the transition of the Italian productive system towards circular models.

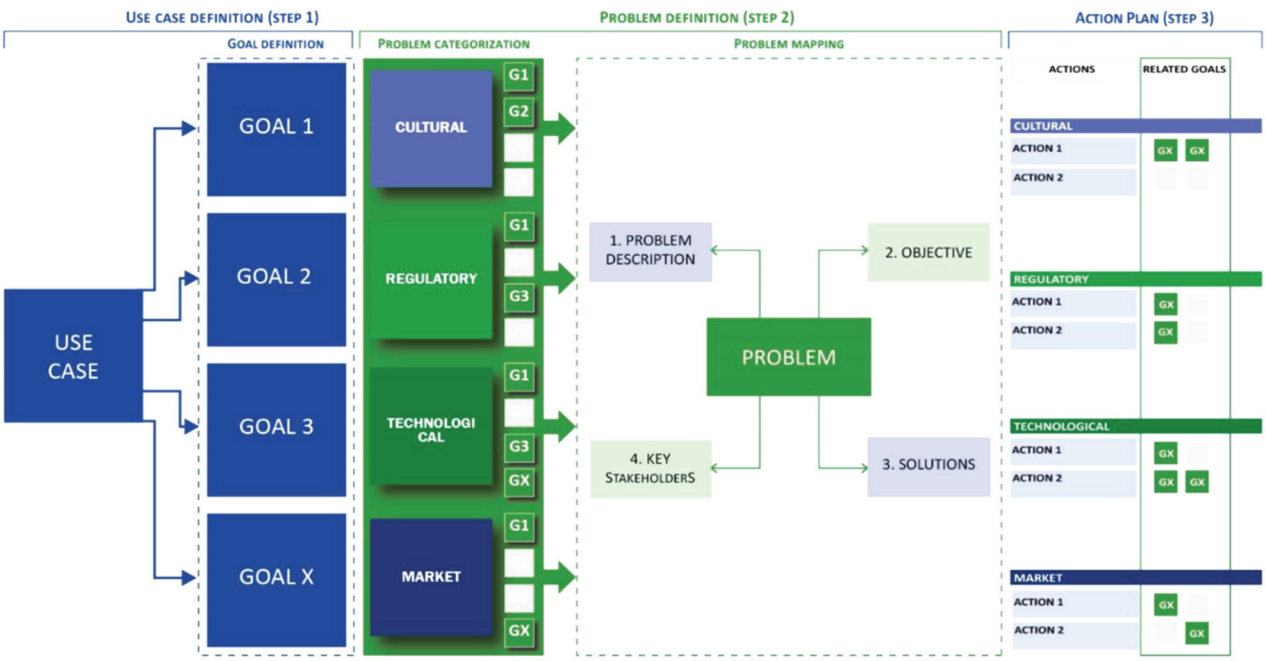

Fig. 2. Methodology diagram (LIFEproETV, 2023a)

It outlines a series of actions to be implemented at defined intervals, providing a roadmap for this crucial transition. In light of the aforementioned reference, ENEA has developed a document entitled "Roadmap for building ETV market acceptance and recognition" (LIFEproETV, 2023b) which was created within the framework of the LIFEproETV project and follows the methodology described above. This document follows the methodology described earlier and aims to define a tangible trajectory for the valorization of ETV. Specifically, it identifies business use cases where an impartial performance audit of innovative environmental technologies can significantly contribute to their implementation and widespread adoption.

The roadmap delineates a series of specific measures to argument the acceptance of ETV in accordance with the identified needs and priorities of the various stakeholders, including policymakers, decision-makers, technology providers, and technology buyers. This accomplished through a comprehensive and active involvement process.

Following the identification of the potential benefits of adopting the ETV as a third-party verification in the CE field, use cases have been defined. The aforementioned use cases have been devised with the objective of facilitating the transition of the ETV from a cost to an added value in the dissemination and marketing of the technology itself.

In this strategic context, it has been determined that the role and utility of the ETV must be defined in relation to the programmatic and strategic objectives of the NSCE, which serve to guide the development of pathways towards the CE. Table 2 presents the selected NSCE-specific objectives. The selection process took into account those issues where technological innovation and improvements in environmental performance are critical to achieving these objectives. In particular, this included areas related to:

- recycling and reuse of materials;
- resources recovery;
- replacing of virgin raw materials with secondary materials.

Concurrently, it delineates the role that ETV could play in the attainment of these objectives. The definition of use cases is the process of identifying obstacles that hinder the achievement of objectives in support of circularity. This process is followed by the identification of concrete actions, which are then categorised based on priority and effectiveness criteria. The objective of this process is to support the construction of a strategic path for the valorisation of ETV in business scenarios. To facilitate this, a stakeholder map was created to identify and engage the relevant stakeholders.

2.1. Obstacles to objectives implementation

In this context, the obstacles to achieving the selected objectives were identified according to the methodology described above. This identification was carried out on the basis of the information gathered from stakeholders involved and consulted during the meetings, conferences and brainstorming sessions organised in the framework of the LIFEproETV project. Once the main barriers were identified, the obstacles were selected according to their nature and classified into four main categories (problem categorisation):

Table 2. Objectives selected from the specific objectives defined by the NSCE and potential role of ETV

Specific NSCE objective	***ETV role***
G1 – Provide tools and services to support companies, especially SMEs, in the implementation of technologies, methodologies and approaches aimed at the efficient and sustainable management of products.	An ETV Statement of Verification can serve as a means of substantiating the efficacy of solutions that prioritise innovation in the domain of optimising material and energy utilisation, thereby enhancing efficiency and mitigating the environmental impact of organisations that adopt such solutions. The utilisation of certified solutions can assist companies in investing in efficacious and profitable solutions, meeting their requirements whilst simultaneously mitigating investment risks.
G2 – Create the conditions for a market of SMR that are competitive in terms of availability, performance and costs, acting on the standardization of materials, and on the criteria for removing the qualification of waste from materials ("End of Waste").	The use of ETV allows for the verification of the performance and environmental impacts associated with the production and regeneration processes of SRM-based materials. It demonstrates that new materials or processes do not result in secondary environmental pollution (especially when using hazardous substances) in comparison to conventional processes. The demonstration of a reduction in the environmental impact of materials produced with the use of secondary raw materials can act as an incentive for their use, thereby increasing the market.
G3 – Create the conditions for a market of "by-products" in terms of greater certainty in recognition, availability, acting on standardization for certain supply chains (e.g., residues and by-products of agricultural origin) and on the revitalization of the by-product exchange platform, to concretely support operators in the full implementation of the IS also in the field of bioeconomy.	ETV offers data on the functional and environmental performance of the by-products, thereby guaranteeing that the material aligns with the stated functional technical parameters for subsequent utilisation as a raw material and to obtain an EoW status certification. This may facilitate standardisation, thereby increasing the exchange of resources between companies (IS).
G4 – Set the conditions for the extension of the life of the product through its design inspired by the principles of modularity and reparability.	The ETV has the potential to serve as a supplementary evaluation scheme for the functional performance of products and technologies with business-to-business (B2B) applications that align with the criteria set forth in the Ecodesign Directive. ETV Statement of Verification may be used as a source of information to support compliance with environmental performance systems for products, including the Environmental Product Declaration (EPD), the Ecolabel, the Product Environmental Footprint (PEF), and the Eco-design Directive.

- *Regulatory problem/barrier:* Lack of a comprehensive framework of tools, standards and policies for the transition to the Circular Economy;
- *Cultural problem/barrier:* Lack of awareness and ability to undertake development paths aimed at supporting the circular economy;
- *Technological problem/barrier:* Lack of effective technologies to implement the circular economy.
- *Market problem/barrier:* Lack of economic feasibility of circular models. A detailed description of the causes contributing to these barriers was developed through a thorough problem mapping process. This exercise led to the following insights for the Italian roadmap;
- *Regulatory:* A significant regulatory obstacle is the absence of a harmonized and clearly defined framework of tools and policies to support the application and use of innovative environmental technologies. To cite one example, the current regulatory framework presents a number of challenges. These include the lack of harmonisation and coordination of test protocols, the scarcity of standards in the field of by-products, and the absence of regulatory recognition of environmental performance measurement tools (such as ETV) in procedures designed to support GPPs.

In the Italian context, the absence of a comprehensive, organic and standardised framework of rules and tools to support circularity represents a significant barrier to the adoption of circular models. This is primarily due to the absence of mandatory product certification, the lack of clarity in the definition of waste and by-product, and the consequent absence of reference standards.

- *Cultural:* Include those barriers deriving from the uncertainty linked to innovation and therefore from the lack of recognition, acceptance and trust in innovations, especially in the environmental field. This uncertainty hampers innovation and the scaling of new solutions. Examples of this include the uncertainty surrounding the diffusion of new technologies on an industrial scale and the reluctance to invest in innovations that lack concrete evidence of improvement in environmental performance. Furthermore, there is a general lack of knowledge

regarding the benefits derived from such innovations (Chen and Wang, 2023 LIFEproETV, 2023a).

With regard to the CE, the lack of awareness and capacity among companies and the market to pursue innovation pathways is frequently associated with a dearth of knowledge regarding processes or services for the transformation and enhancement of waste.

- *Technological:* However, these technologies often fail to achieve significant market penetration, as potential users remain skeptical about their effectiveness. As a result, many users are hesitant to adopt new technologies until their benefits have been clearly demonstrated. This leads to significant challenges in upscaling innovations, with many technologies remaining at the pilot stage or failing to gain the market traction necessary for widespread adoption.

- *Market*: Economic barriers play a major role in hindering market entry for circular economy solutions. These barriers include the high initial costs of innovation, the scarcity of funding to support new technologies, and the tendency to focus on short-term financial gains rather than the long-term economic benefits of cutting-edge solutions. The lack of economic viability and the necessity for significant investment to stimulate innovation in the utilisation of secondary raw materials or in the preparation of MPS for use in other production processes represent the most prevalent factors impeding the dissemination and adoption of innovative environmental solutions. With regard to the transition towards the CE, one of the principal obstacles is the relatively low price of virgin materials, which acts as a disincentive to the use of recycled materials.

2.2. Solutions and opportunities

In accordance with the methodology, the problem mapping entails the simultaneous development of solutions for its resolution, while also considering the potential opportunities that may arise from it. This phase therefore highlights how ETV can support strategies to overcome barriers in the transition to a CE. From a regulatory perspective, ETV has the potential to become a CE standard for verifying the performance of a number of emerging technologies, including those that facilitate the conversion of waste into resources, as well as secondary raw materials destined for industrial applications and products based on secondary raw materials.

The adoption of ETV as a standard could provide a robust basis upon which to address regulatory gaps related to the performance of technologies and materials. Furthermore, at the national level, ETV, as a reliable system, could be acknowledged by regulators as a means of demonstrating compliance with BAT performance levels.

As ETV provides an impartial assessment of environmental performance, it could be employed as a methodology for demonstrating compliance with technical specifications in national GPP. ETV verification statements can further substantiate compliance with various environmental performance systems, such as EPD, ecolabel, Environmental Product Footprint (PEF), and eco-design.

With regard to the issue of cultural barriers, ETV can assist in establishing credibility for to innovative technologies by verifying performance in relation to resource use. This can assist technology purchasers in mitigating the technological risks associated with investment, and provide companies with a genuine opportunity to embark on IS pathways based on an audit that highlights the benefits. Moreover, ETV can provide certification attesting to the benefits of innovative technologies, namely their capacity to reduce adverse impacts on human health and the environment. It can also facilitate the process by which companies can obtain permits allowing them to transform their waste into valuable by-products or SRM.

To overcome the technological obstacles that hinder the progression of environmental solutions, ETV plays a pivotal role in defining the technological potential and viability of these innovations in addressing environmental concerns. Furthermore, the flexibility in selecting evaluation parameters allows the identification of the most suitable technology to address specific environmental challenges. Furthermore, ETV can facilitate the dissemination and market acceptance of innovative environmental technologies, as it can inform the establishment of appropriate and meaningful incentives for manufacturers, suppliers, buyers, and users of ETV-verified technologies.

Moreover, incorporating ETV into GPP and IP procedures, as a compliance verification tool could be highly beneficial. This would involve aligning ETV with test reports from conformity assessments and establishing a verification statement similar to the Ecolabel. Such an approach could significantly enhance the market acceptance of innovative environmental technologies by providing credible, third-party verified evidence of their performance.

Additionally, focusing on Small and Medium Enterprises (SMEs), which are agile and well-positioned to drive the transition to a circular economy, ETV could help SMEs create non-financial statements to showcase the viability of circular business models. This would promote their adoption of sustainable practices and demonstrate the environmental and economic benefits of circular approaches.

2.3. Action plan

For each of the aforementioned problem category, which encompass regulatory, market, technological, and cultural concerns, a set of defined actions has been established.

i. Regulatory actions:

- Integrate ETV as CE standard: The ETV

scheme should be adopted as the standard for CE practices, providing a market-relevant framework for future legislation. This would address regulatory gaps related to product-integrated environmental protection and performance-based regulations, particularly for technologies and materials involved in circular processes.

- Use ETV for BAT Compliance: ETV should be utilized to demonstrate compliance with performance levels for BAT. By implementing ETV-verified technologies, companies can reduce uncertainties regarding the potential environmental benefits of these technologies.

- Recognize ETV in National GPP: ETV should be recognized within national GPP frameworks. This would offer a systematic methodology for verifying compliance with technical specifications, while also supporting a comprehensive life cycle approach to product and technology evaluation.

ii. Cultural actions:

- Disseminate knowledge of ETV: Efforts should be made to disseminate knowledge about the ETV system through collaboration with various stakeholders involved in innovation support. This will help raise awareness and understanding of ETV's benefits across different sectors.

- Promote ETV to streamline technology scaling: ETV should be promoted as a tool to facilitate dialogue and streamline administrative processes for scaling up innovative technologies at the European and national levels. This will help create a more supportive environment for technological innovation.

- Enhance information access for SMEs and Start-ups: It is essential to improve access to information about ETV, particularly for SMEs and start-ups. This can be achieved by strengthening the role of business support organizations, which can provide guidance on the adoption and benefits of ETV.

iii. Technological actions:

- Facilitate industrial-scale replication: Conditions should be created that allow for the industrial-scale replication of innovative technologies by using the ETV verification process as a formal validation protocol. This will help reduce investment risks and increase the competitiveness of emerging technologies compared to traditional alternatives.

iv. Market actions:

- Incorporate ETV into national innovation policies: ETV should be integrated into national policies aimed at fostering innovation, particularly in SMEs. This can be achieved by providing economic incentives such as tax deductions or subsidies for the development and adoption of new environmental technologies.

- Promote ETV with a Focus on Environmental Benefits: In addition to highlighting the market potential of ETV-verified technologies, emphasis should be placed on the environmental benefits these technologies provide. This will not only help accelerate market acceptance but also contribute to achieving environmental goals at the local and community levels.

3. Result and discussions

In the overall objective of this study, the aim is to boost awareness, market recognition, and acceptance of ETV scheme. Market acceptance has two aspects: Firstly, it measures the extent to which ETV satisfies stakeholders, in particular technology buyers and providers. Technology buyers must perceive ETV as a valuable support mechanism that simplifies their decision-making processes, clarifies their options, and assists them in overcoming challenges related to purchasing and technology selection. Conversely, technology providers need to see a compelling business case that justifies their participation in the ETV scheme, ensuring that it adds value to their offerings and enhances their market competitiveness. Secondly, market acceptance encompasses a broader adoption process wherein various market actors incorporate ETV into their operations and strategies.

Beyond the core target groups, other stakeholders such as policymakers, research and innovation (R&I) program operators, regulatory bodies, and investors have their unique needs and motivations for utilizing ETV. Each of these stakeholders may adopt the ETV framework to serve their specific objectives, whether it is to promote regulatory compliance, leverage technological innovation, attract investments, or align with sustainability goals. Their engagement is crucial, as it contributes to the overall market uptake of ETV, ensuring that it remains relevant and effective across different contexts and applications.

Market recognition plays a crucial role in the success of a product or service, such as ETV (Environmental Technology Verification). When a technology or service is widely recognized, it significantly influences the purchasing decisions of both technology providers and buyers. The project has therefore developed an innovative methodology for the co-creation of collaborative institutional ecosystems, with the aim of actively involving all key stakeholders in the promotion and adoption of the ETV scheme. This approach is particularly valuable because it is embedded in a concrete national context, allowing environmental challenges to be addressed with strategies tailored to local specificities.

The project not only promotes the adoption of this methodology, but also aims to support long-term sustainable development. The cooperation between the different actors involved enables the integration of skills and resources, the creation of a more favourable regulatory environment and the raising of awareness of the importance of innovative environmental technologies. Based on the guidance provided by the concrete ETV use case, discussed and detailed in the Italian roadmap, the creation of a collaborative ecosystem was successfully initiated. In fact, as

Knowledge Centre and potential national Scheme Owner (responsible for the development and maintenance of a compliant scheme and for the definition and application of rules for the use of the scheme in different technological contexts), ENEA has defined a collaborative ecosystem as detailed in the chart in

Fig. **3**, which envisages the interaction with different subjects and stakeholders with whom collaboration has already been initiated.

These activities are currently in place and will continue in the next phase of the After Life Plan, i.e. a strategic plan aimed at ensuring the durability and persistence of the project results over time and the resources required for their application. To date, the construction of the network for the implementation of the ecosystem has seen the active involvement of numerous institutional actors, business associations and individual organisations. ENEA, in particular, has organised and participated in 13 events, including conferences and workshops, at which it has presented ETV to specific target audiences, gauging the interest of various actors in utilising and disseminating the ETV scheme. The promotional campaign for the ETV initiative in Italy, which integrates within the national strategies for circular economic development, has significantly advanced key objectives. The main outcomes can be summarized as follows:

- *Network expansion:* Targeted meetings successfully defined and broadened a collaborative network, identifying two additional prospective knowledge centres for ETV in addition to ENEA.

- *Strengthened partnerships:* The initiative enhanced partnerships with existing circular economy platforms and their member organizations, fostering a collaborative approach to identify innovative circular economy technologies eligible for ETV.

- *Increased awareness:* The advantages of ETV in facilitating the transition to circular economic models were communicated effectively to organizations that promote the adoption of new technologies among businesses. This effort has led to a deeper and more contextual understanding of ETV's role and its benefits in promoting green technologies.

- *Outreach and education:* Awareness of the ETV initiative surged, aided by the distribution of promotional videos and interviews in specialized journals and magazines focused on the circular economy. Additionally, many small and medium-sized enterprises, along with the scientific research community, received in-depth information about ETV through workshops conducted during the campaign.

These outcomes highlight the effectiveness of the campaign in building a robust framework for promoting ETV as an essential tool for advancing Italy's circular economy objectives and driving the adoption of sustainable technologies.

4. Conclusions

The role and applications of ETV can vary depending on the stage of the product and process life cycle under consideration. It serves to demonstrate the efficacy of the reduction in the utilisation of primary materials and energy, as well as the promotion of the adoption of technologies that have been verified and deemed reliable, which enhance the efficiency of companies while minimising the environmental impact. Furthermore, ETV plays a pivotal role in demonstrating the implementation in the use of SRM to guarantee that new materials or processes do not lead to secondary pollution.

This approach, facilitates the overcoming of obstacles to the development of industrial symbiosis (IS) pathways, a collaborative model involving traditionally separate industries in a collective approach to competitive advantage involving the physical exchange of materials, energy, water and by-products. The key to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity and circular business models while verifying that these processes do not result in environmental harm.

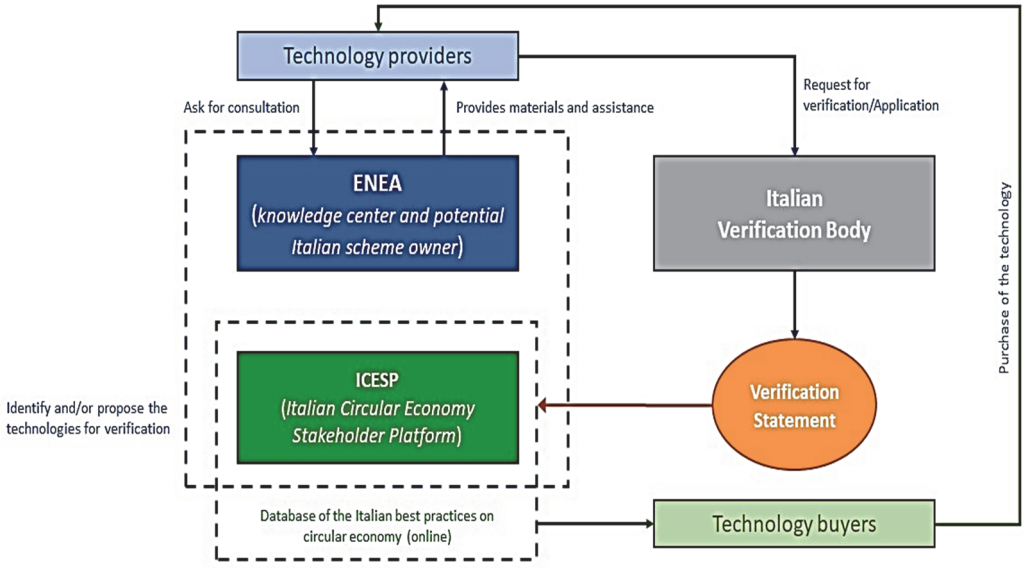

Fig. 3. ETV ecosystem for Italy

Furthermore, ETV can furnish data regarding the functional and environmental performance of by-products and product parts intended for circular applications in industry.

Furthermore, ETV Verification Statements ensure that verified by-products meet the necessary technical and functional criteria for subsequent use, including the issuance of an End-of-Waste. The role of the ETV is of great importance in the promotion of sustainable practices and the fostering of a CE. The role of the ETV in promoting green innovation in public procurement (GPP and IP) could be pivotal, as it serves as a conformity assessment tool and is acknowledged as an equivalent means of proof. Additionally, ETV Statements of Verification can furnish information that is instrumental in guaranteeing that products meet environmental performance standards, including those set forth in the EPD, Ecolabel, PEF, and Eco-design.

To achieve these objectives, a collaborative network was established to create a robust ecosystem that supports ETV. The active involvement of specific target groups helped to strengthen the solidity of the ecosystem and lay the foundations for the sustainability of the project results. In fact, the promotion campaign conducted so far has involved and informed institutional bodies, local authorities involved in GPP and policy makers who are actively involved in the implementation of policies aimed at supporting the transition to a circular economy. The ecosystem described is designed to improve collaboration and verification processes, particularly in the context of ETV.

By fostering a favourable environment for innovative technologies, these ecosystems not only facilitate the adoption of ETV, but also promote the dissemination and replication of project results. This model can serve as a valuable reference for other countries or sectors seeking to exploit the benefits of ETV, enabling them to capitalise on the opportunities it presents for sustainable development and technological progress.

By showcasing use cases and success stories, these ecosystems can inspire confidence and encourage broader engagement in ETV practices, ultimately fostering progress towards environmental sustainability and innovation.

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