



Enforce
Empowering Citizens for Environmental Action

D2.1 Environmental Compliance

A review

WP2 - ENFORCE methodology and Data-Driven Roadmap for ECCI

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Authors: Anna Berti Suman (A Sud); Georgia Tseva (UTH); Sofia Gourgouliani (UTH); Chrysi Laspidou (UTH); Manos Christofakakis (HBA).

Contributors: Vanessa-Sarah Salvo (CSIC); Spela Zalokar, Bertille Auvray (ENoLL); Marta Lovato, Alessia Tisci, Sara Vegni, Ana Maria Pulido (A Sud); Mirabela Marin, Hapa Ionut Mihai, Cezar Ungurean, Tudose Nicu Constantin (NIRDF), Florentina Nanu, Ciprian Nanu (BDG), Ifigeneia Tsakalogianni (HU); Matthew Worthington; Francis Rowney; Nicola Rogers (WRT); Anne Wijnen; Nehis Osagie (Waag); Vanessa Boas, Linda See (IIASA); Isayvani Naicker (Evisights).

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Authors	Anna Berti Suman (A Sud); Georgia Tseva (UTH); Sofia Gourgouliani (UTH); Chrysi Laspidou (UTH); Manos Christofakakis (HBA).
Contributors	Vanessa-Sarah Salvo (CSIC); Spela Zalokar, Bertille Auvray (ENoLL); Marta Lovato, Alessia Tisci, Sara Vegni, Ana Maria Pulido (A Sud); Mirabela Marin, Hapa Ionut Mihai, Cezar Ungurean, Tudose Nicu Constantin (NIRDF), Florentina Nanu, Ciprian Nanu (BDG), Ifigeneia Tsakalogianni (HU) Matthew Worthington; Francis Rowney; Nicola Rogers (WRT) Anne Wijnen; Nehis Osagie (Waag); Isayvani Naicker (Evisights); Vanessa Boas, Linda See (IIASA)
Primary Contact and Email	Anna Berti Suman (A Sud) annabertisuman@asud.net
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Deliverable Abstract

The deliverable offers a review and analytical synthesis of current policy, strategy and underlying concepts relating to environmental compliance and innovation that have emerged from research, projects, academic and grey literature, and the media. The deliverable is essential for informing WP3 of the project, aimed at developing the ENFORCE Plaza Tools, and WP4, aimed at Case Studies Coordination and Implementation, through Living Labs setup and co-creation and co-design with citizens and stakeholders. The Deliverable is also strategic for our user and policy impact WP5, focused on user uptake, capacity building and policy recommendations. D2.1 starts with outlining the project's working language by presenting the ENFORCE Glossary and the methodology for building it. Then, we dive into the work of building a conceptual framework that will support the Environmental Compliance through Citizens and Innovation (ECCI) structure and offers guidance for the following implementation of ENFORCE's theory of change. We call this guidance a 'Roadmap for ECCI'. We illustrate the secondary data collection performed across three project's tasks and respective tables, T2.1-2.3. Furthermore, we discuss our primary data collection in the framework of T2.3 through a public survey and follow-up interviews. We narrow down practical lessons from primary and secondary sources and good practices in collecting evidence to make the results obtained more case study specific. In essence, the deliverable offers a roadmap to guide partners, citizens innovators and other interested users to leverage citizen science potential for compliance assurance, based on the key insights from the research performed.

Keywords

ENFORCE; citizen science; environmental compliance; socio-technical innovation; law and policy review; survey; interviews; roadmap.

Project Summary

Assuring environmental compliance requires a strong network of stakeholders, from citizens and researchers to governments and environmental organisations. Through development of creative toolkits and protocols, ENFORCE aims to tackle the frequent mismatch between the environmental data gathered by citizens and what authorities require for enforcement purposes. The project will address the challenges in data reporting coming from both the citizens side and the authorities' side, in order for the obtained data to be usable for environmental enforcement. In this line, ENFORCE introduces the concept of Data Readiness Level (DRL) to assess the maturity of data to be used as evidence in environmental compliance cases. In addition, the project will capitalize on the use of geo-spatial intelligence and AI-enhanced tools, strengthening their capacities, promoting good practices and preparing an inventory on geo-spatial intelligence and Artificial Intelligence (AI) use. The proposed solution will ensure alignment with the Green Deal Data Space to ensure trustworthy data exchange among the relevant stakeholders. The project encompasses 8 case studies that involve all relevant actors including grassroots organizations, local and regional authorities and a diverse group of experienced researchers forming a scientifically robust interdisciplinary team. The lessons learnt and evaluation results from the case studies will feed the replication guidelines that will be promoted through the ENFORCE capacity building programme and associated policy recommendations to create a multiplier effect for the adoption of citizen science data to support environmental compliance.

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Table 1 - List of abbreviations

Abbreviations	Meaning
AI	Artificial Intelligence
ARPA	Italian Regional Protection Authority [Agenzia Regionale per la Protezione Ambientale]
CA	Compliance Assurance
CAT	Critical Accounting Theory
CNR	National Research Council Italy [Consiglio Nazionale delle Ricerche]
CS	Citizen Science
DABM	Flemish Environmental Policy Decree [Decreet houdende algemene bepalingen inzake milieubeleid]
DANE	National Statistics Department Colombia [Departamento Administrativo Nacional de Estadística]
DRL	Data Readiness Level
EA	Environmental authority
Earth Observation	EO
ECCI	Environmental Compliance through Citizens and Innovation
EC-DRL	Data Readiness Level for Environmental Compliance
ECSA	European Citizen Science Association
EGDDS	European Green Deal Data Spaces
EU	European Union
GBIF	Global Biodiversity Information Facility
KPI	Key Performance Indicator
NGO	Non-Governmental Organization
RIVM	Dutch Institute for Health and the Environment [Rijksinstituut voor Volksgezondheid en Milieu]
SME	Small-medium Enterprise
WP	Work Package
NGO	Non-Governmental Organization

Executive Summary

The deliverable offers a review and analytical synthesis of current main policy, strategy and underlying concepts relating to environmental compliance and innovation that have emerged from research, projects, academic and grey literature, and the media collected by the consortium. The deliverable does not claim to be exhaustive but rather offers a focused and precise analysis of the three areas of interest of ENFORCE: biodiversity, pollution and forest management. This document is essential for informing: i) WP3 of the project, i.e., aimed at developing the ENFORCE Plaza Tools; ii) WP4, aimed at Case Studies Coordination and Implementation, through Living Labs setup and co-creation and co-design with citizens and stakeholders, and iii) WP5, our user and policy impact WP, focused on user uptake, capacity building and policy recommendations.

D2.1 starts with outlining the project's working language by presenting the ENFORCE Glossary and the methodology for building it. Then, we dive into the work of building a conceptual framework that will support the ECCI structure and offers guidance for the following implementation of ENFORCE's theory of change, as outlined in Section 1.2. We call this guidance a 'Roadmap for ECCI'. We illustrate the secondary data collection performed across three projects' tasks and respective tables, T2.1-2-3, which are made available in Open Access on Zenodo.¹ The key lessons emerged from this review of policy and laws, procedural legislations and judicial cases, and literature are illustrated. Furthermore, we discuss our primary data collection in the framework of T2.3 through a public survey and follow-up of semi-structured interviews.² From this data collection insights are discussed for informing the conceptual framework.

In summary, the deliverable defines the core concepts underpinning the project's approach to compliance and situates them within the broader evolution of compliance thinking. It introduces the ENFORCE approach as a sociotechnical framework for strengthening compliance assurance in the fields of pollution control, forest logging, and biodiversity protection. Drawing on primary and secondary sources, the analysis distils practical lessons and good practices on evidence generation and use, with the objective of informing – rather than replicating – case-specific applications. The deliverable concludes by providing practical guidance to enable citizens to collect relevant evidence and to support enforcement authorities, including police forces, environmental monitoring agencies, and prosecutors, in effectively using citizen-generated evidence for compliance assurance. It pays particular attention to challenges related to knowledge flows across governance levels, from the EU and regional to the local level. Overall, the deliverable functions as a conceptual and operational roadmap, setting out key principles, tools, and methods for integrating citizen science into compliance processes, with detailed implementation addressed in the WP4 case studies.

¹ DOI: [10.5281/zenodo.17902173](https://doi.org/10.5281/zenodo.17902173).

² Whereas in the perception survey deployed for T2.3 the gender dimension was not a specific question analysed (we decided that it was not needed for the focus of our inquiry, in light of the data minimization principle), in the follow-up interviews we ensured that both the pool of invited prospect participants and the actual people invited to the interviews were balanced in terms of gender.

1. Introduction

1.1 The ENFORCE project

The international project **ENFORCE**, supported by Horizon Europe funding (Grant agreement 101134447) ³ aims to **leverage CS and innovative technologies** to ensure that locally collected environmental data and information meets the standards and formats required by authorities for **promoting environmental compliance**. By *environmental compliance*, we mean the various ways in which public authorities promote, monitor and enforce environmental law and policies.⁴ Ensuring environmental compliance is essential for protecting natural resources and mitigating the impacts of pollution on ecosystems, and on human and animal health. Enforcement deters potential offenders but is inefficient without monitoring. Indeed, **to effectively enact environmental compliance, there is the need to improve monitoring** enforcement and to refine effective legal and policy frameworks. At the same time, however, environmental agencies and inspectorates face persistent capacity constraints, which significantly limits their ability to systematically monitor and enforce compliance across the extensive territories for which they are responsible.

ENFORCE posits that civil society can support environmental compliance, in particular through performing environmental monitoring and gathering environmental data by engaging in CS activities. *Citizen science* refers to activities in which non-professional participants contribute to scientific research including data collection and in some cases data analysis to advance knowledge in the environmental field.⁵ We also stress the need to inform civil society of the applicable legal and policy frameworks on environmental compliance, and on the benefits of their involvement. ENFORCE aims to empower it with tools that we co-create together and to form collaborations with state agencies so civil society can play an important role in supporting compliance. Citizen-generated data stemming from CS projects need to be **integrated within official data sets at the national and EU level**, in particular within the EGDDS⁶ to be used effectively in order to advance compliance.

Furthermore, data collected by citizens and satellite images supporting in-situ gathered data need to be **used in court proceedings** to demonstrate environmental incompliance. ENFORCE is supporting civil society initiatives to ensure that their locally collected data can **meet the applicable standards to be used for compliance assurance**. In addition, the project is contributing to the integration of civic data with geospatial data through the development of

³ To know more about the project, visit its website at: <https://join-enforce.eu/>.

⁴ Find out more at: https://environment.ec.europa.eu/law-and-governance/environmental-compliance-assurance_en. See also the ENFORCE Glossary available on Zenodo: <https://doi.org/10.5281/zenodo.17901267>.

⁵ To know more, see: <https://royalsocietypublishing.org/doi/10.1098/rsos.202108>. As a note, we stress that in the context of citizen science, the reference to citizenship is synonymous with 'people', including also those who do not hold specific citizenship rights of a certain nation.

⁶ See <https://green-deal-dataspace.eu/>.

integrated systems and tools that use satellite images, AI and advanced visualization tools. to enable monitoring and enforcement of environmental compliance.

1.2 Theory of change behind ENFORCE

At the policy level, theory of change has been defined as “a method that explains how a given intervention, or set of interventions, are expected to lead to a specific development change, drawing on a causal analysis based on available evidence” (UN Development Group, 2017: 4). The **theory of change** behind ENFORCE is a future in which:

- Data on environmental compliance is available, accessible, free and open to all, and their data sources are independent, making them admissible to court as evidence.
- Authorities are aware of the possibility to use satellite and citizen data, along with other data available from public authorities for environmental auditing.
- Data processing from authorities at all levels is relatively simple and does not require extensive expertise.
- Citizens are much more involved and active in ensuring that their surroundings are monitored for environmental compliance and can play a role in keeping environmental crime low.
- Citizens are using digital tools to interact with enforcement authorities, and such tools are used to meet environmental compliance challenges.
- The project’s deployed tools are effectively used to prevent environmental crimes, by focusing on pre-crime risk tipping points and on crime triaging by citizens.
- Rates of monitoring, compliance, enforcement and successful prosecution increase, resulting in more pro-active behaviours in relation to preventing environmental damage and harm, thus increasing overall positive impacts for environmental health.
- When a case of environmental incompliance does occur, citizen-gathered data can now be certified for their authenticity and explainability, so they can easily be introduced as court evidence.
- Elements of environmental compliance including methods, knowledge, datasets, tools and citizens as well as best practices and success stories are all found in one place: the ENFORCE Plaza.
- New opportunities are created, including for businesses, such as small-medium enterprises and start-ups. Living Labs are set up in the 8 Case Studies selected by the project to promote collaboration and co-creation between citizens and key stakeholders, including enforcement authorities.
- Best practices and success stories are publicised and replicated beyond the location of the Case Studies through strong campaigns and building strong networks.
- One or more use cases on environmental compliance are developed for the Green Deal Data Space combining citizen data with other public data for future use.
- The EU ecosystem is informed on the current and upcoming capabilities of Earth Observation for environmental compliance.

- Despite the limited staff in local and regional Environmental Agencies, regions and protected areas are being monitored by citizens and Earth Observation tools, using civic and geospatial intelligence, digital applications, sensors, etc.
- Among others, the European Green Deal and relevant laws and policies, such as the Biodiversity Strategy, the new Environmental Crimes Directive, the Water Framework Directive, the Marine Strategy Framework Directive and the EU Timber Act are being observed and succeed in safeguarding the environment.

Evidently, the outlined theory of change adopted by ENFORCE aligns with a growing body of environmental governance research that argues for a shift from incremental improvements to genuinely transformative approaches. Scholars increasingly point out that environmental problems persist not simply because technologies or data are insufficient, but because governance systems, institutions, legal frameworks, information flows and participation structures are **not configured to support deep and lasting change**. Korhonen-Kurki et al. (2025) underline that transformative governance requires interventions that widen participation, strengthen transparency, foster learning and stimulate institutional innovation. This argument is echoed by Blythe et al. (2021), who emphasise that sustainability transformations involve political choices, power struggles and opportunities to reshape who influences environmental decision-making.

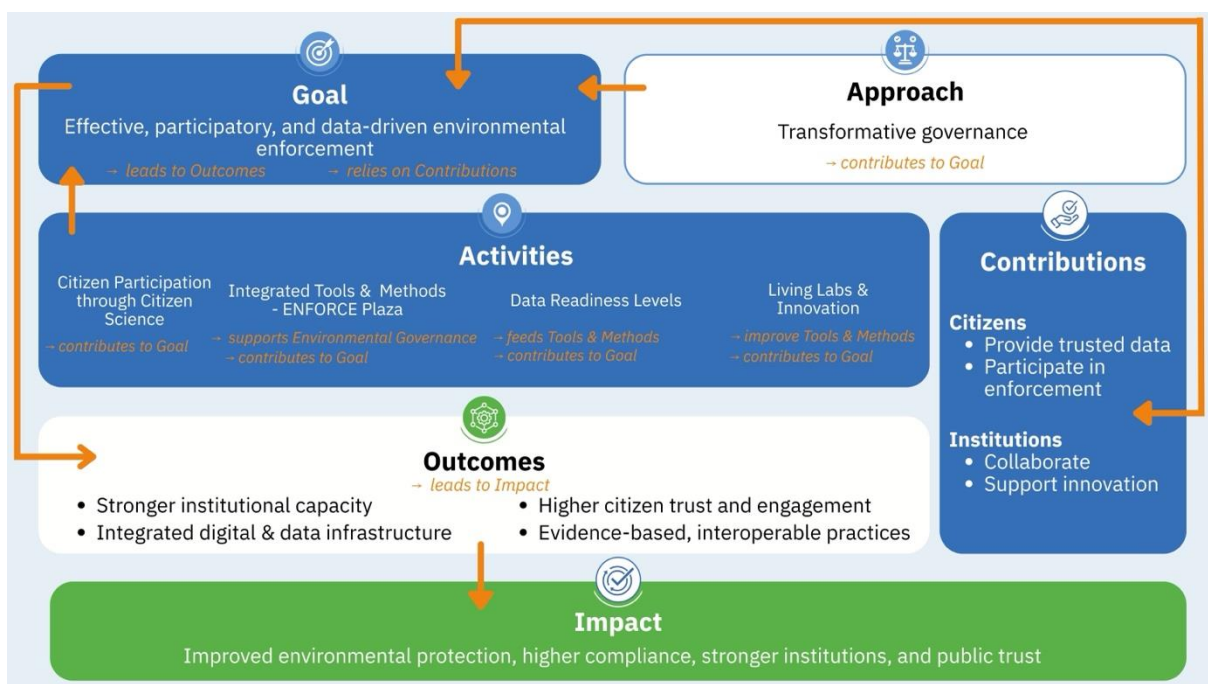


Figure 1 - Theory of Change in ENFORCE

The design of ENFORCE reflects these insights. The project strengthens environmental governance by **making compliance data open, independent and legally robust**, which enhances the credibility and transparency of evidence used in enforcement processes. Citizens gain meaningful roles in monitoring through accessible digital tools, and the Living Labs invite

communities, SMEs and authorities to work together on shared challenges. These collaborative spaces encourage experimentation and create opportunities for innovations to take root. The development of the ENFORCE Plaza further supports systemic change by **consolidating knowledge, methods and good practices** in a way that enables wide dissemination and replication.

Contemporary scholarship reinforces the value of this approach. Patterson et al. (2021) highlight the importance of **addressing underlying political and institutional dynamics that often inhibit transformation**. Moore et al. (2024) add that social-ecological transformations succeed when governance interventions improve information exchange, encourage coordinated action and nurture **adaptive, forward-looking institutional cultures**. ENFORCE's theory of change reflects these principles through its focus on strengthening relationships between data, institutions and society, and through its ambition to build governance systems that are more participatory, transparent and capable of responding proactively to environmental challenges. In doing so, the project contributes both to improved compliance, but also to the **broader evolution of environmental governance** toward transformative and resilient futures.

1.3 Role and structure of the deliverable

In the framework of the ENFORCE project, this deliverable is inserted within Work Package 2 (WP2). WP2 has the aim i) to establish the conceptual underpinning of the project, providing a conceptual and analytical framework to connect **ECCI and KPIs** for impact evaluation; ii) to provide a systemic understanding of current barriers and enablers to ECCI; iii) to provide a roadmap of existing knowledge; iv) to provide training and a common language for the consortium partners. The deliverable offers **a review and analytical synthesis of current policy, strategy and underlying concepts relating to environmental compliance and innovation** that have emerged from research, projects, academic and grey literature, and the media. The deliverable is essential for informing: i) WP3 of the project, aimed at developing the ENFORCE Plaza Tools; ii) WP4, aimed at Case Studies Coordination and Implementation, through Living Labs setup and co-creation and co-design with citizens and stakeholders ; iii) WP5, our user and policy impact WP, focused on user uptake, capacity building and policy recommendations. The figure below outlines the interconnected nature of the WPs.

D2.1 starts with outlining the project's working language by presenting the **ENFORCE Glossary**⁷ and the methodology for building it. Then, we dive into the work of **building a conceptual framework** that will serve as a roadmap for ECCI. We illustrate the **secondary data collection** performed across three project's tasks and respective tables, T2.1-2-3, which are made available in Open Access.⁸

⁷ See <https://doi.org/10.5281/zenodo.17901267>.

⁸ See <https://doi.org/10.5281/zenodo.17902173>.

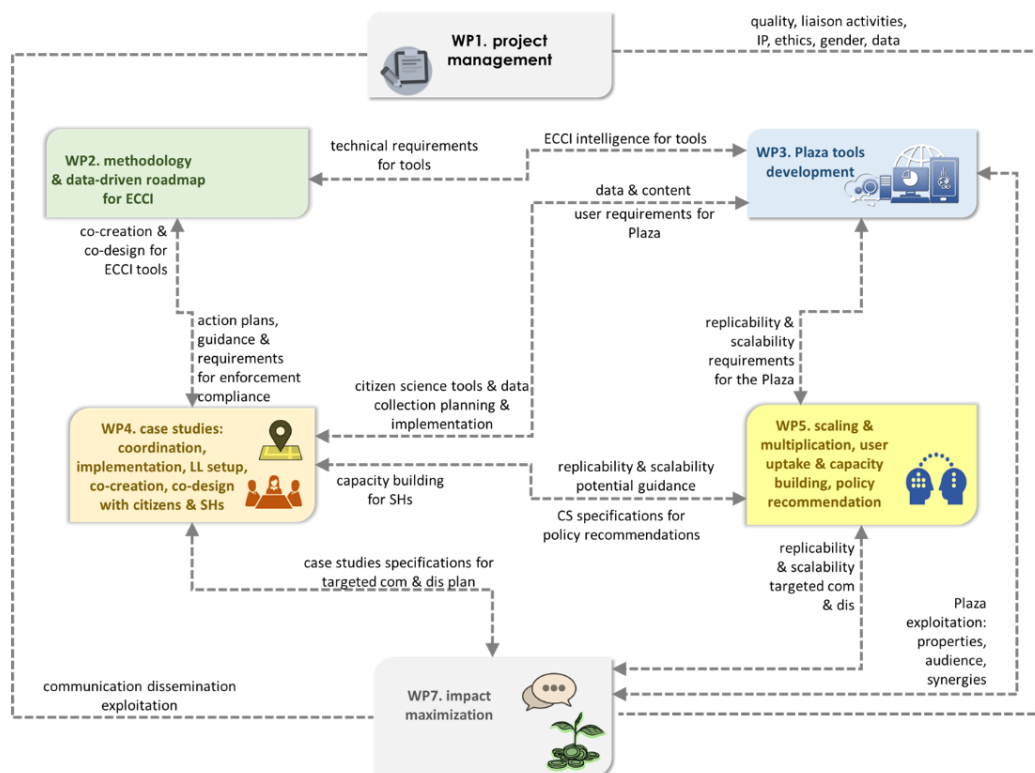


Figure 2 - Pert Chart of the project's structure

The key lessons emerged from this review of policies and laws, procedural legislations and judicial cases, and literature are illustrated. Furthermore, we discuss our **primary data collection** in the framework of T2.3 through a public survey and follow-up interviews. Also, from this data collection key insights are discussed for informing the conceptual framework.

The deliverable proceeds by outlining key concepts that identify our understanding of compliance, the evolution of compliance thinking and our approach as ENFORCE project, **bridging sociotechnical innovation for compliance assurance** in the areas of pollution, forest logging and biodiversity protection. We narrow down **practical lessons from primary and secondary sources and good practices** in collecting evidence to make the results obtained more case study specific. We conclude with a **practical guide empowering citizens in collecting evidence and prosecutors in using evidence** originating from citizens for compliance assurance.

We also address the quest for transferring knowledge from the EU and regional levels to the local level. We illustrate the ENFORCE approach, outlining existing tools, methods, and fixes under review boosting citizen science potential from a compliance perspective in the project's case studies supported through WP4. The deliverable essentially offers **a roadmap to guide partners, innovators, civil society, practitioners and other interested users to leverage CS potential for compliance assurance**, based on the key insights gathered from the review and research performed.

1.4 Target audience

The field of environmental compliance assurance spans local, national, and international institutions. The stakeholders actively involved by the European Commission in the implementation of these policies are environment agencies, inspectorates, police officers, prosecutors, and judges. To better understand potential gaps, the range of the audience has been extended within the framework of the ENFORCE project to get a more comprehensive picture.

The following **target groups** have been identified as major stakeholders that are being engaged and consulted throughout the project, and will be invited to validate the project's outcomes:

- Environmental agencies and institutes;
- Inspectorates and law enforcement entities;
- Judges and prosecutors;
- Legislators and policymakers;
- Technology developers and providers;
- Scientific community and academic institutions;
- International, European and national thematic networks, clusters and multipliers;
- Civil society, associations and non-governmental organizations (NGOs);
- Forest and landowners, and administrators of natural resources.
- Activists
- Citizen scientists/ data collectors
- General public

2. The project's working language: the Glossary

2.1 Methodology for building the ENFORCE Glossary

The development of the **ENFORCE Glossary** (available in Open Access on the project's Zenodo repository)⁹ followed a structured and participatory methodology that combined desk research, partner engagement, and iterative validation. This process was designed to ensure that the Glossary fulfils a dual purpose within the project: first, as a detailed internal reference tool to support the consortium in achieving conceptual clarity and consistent communication, and second, as a publicly accessible resource that enhances dissemination, stakeholder engagement, and sustainability beyond the life of the project's dissemination, stakeholder engagement, and sustainability beyond the life of the project.

The process began with a period of **internal research and structuring** between months one and four (M01–M04). During this stage, partners carried out desk-based research drawing upon existing glossaries, scientific literature, EU legislation, and international environmental compliance frameworks. At the same time, a consensus was reached on the purpose and intended

⁹ See <https://doi.org/10.5281/zenodo.17901267>.

audience of the Glossary. It was agreed that the primary goal was to create a shared understanding of environmental compliance concepts within the ENFORCE project, while also developing a resource that could be made publicly available to support students, policymakers, stakeholders, and citizens. This **dual orientation** ensured that the Glossary would serve both as an internal tool for precision and coordination, and as an accessible instrument for knowledge dissemination and engagement beyond the consortium.

Draft entries were then developed and organized according to the ENFORCE and ECCI thematic tags, which included (1) project management, (2) environmental compliance approach, (3) data, (4) models and tools, (5) citizen and stakeholder engagement, (6) knowledge and capacity building, and (7) exploitation, replication and sustainability. Entries prepared during this phase were technical in orientation, containing definitions, references, and contextual notes intended to support partners in their ongoing work. Based on this, between months five and seven (M05–M07), the draft glossary was circulated for partner feedback.

The next stage, running from months eight to ten (M08–M10), focused on **analysis and validation**. Feedback was consolidated, redundancies and inconsistencies were addressed, and thematic harmonisation was undertaken across the seven tags. This stage culminated in a validation workshop, which was held on 20 June 2025, where partners engaged directly with the draft glossary in order to test its relevance in project-related contexts. The workshop clarified terminology but also strengthened shared understanding of complex processes and built confidence in the glossary as a tool for internal coherence and external communication. The implementation of the validation workshop relied on collective reading methods, which encouraged active listening, shared comprehension, and the breakdown of complex ideas. Consortium members reviewed and selected tags aligned with their work, proposed additional terms, refined existing definitions, and contributed suggestions for simplified entries that could be adapted for public use. A structured feedback form guided this process, inviting reflections on how the glossary was likely to be used, challenges encountered in accessing or applying terms, the level of detail expected, and the frequency with which updates should be made.

Finally, in months eleven to twelve (M11–M12), the glossary was **refined into two outputs**. The **internal working glossary** was maintained in Microsoft OneNote, offering detailed definitions, references, and cross-links that support consistent usage and update across deliverables and project activities. In parallel, a targeted public glossary was produced with focused and accessible definitions and contextual explanations tailored for stakeholders, policymakers, and citizens. The **public version** is made available on Zenodo¹⁰ in user-friendly formats, i.e., downloadable spreadsheet. Lastly, translations into partner languages will be performed if needed to facilitate accessibility.

Overall, the methodological steps followed for the development of the glossary integrated previous knowledge on the creation of a glossary in collaborative research projects (Velardi et al. 2006) with **desk research and collaborative validation processes**. In this process,

¹⁰ See <https://doi.org/10.5281/zenodo.17901267>.

sustainability is embedded in the methodology through a planned update cycle, which has been determined collectively by the consortium. Updates will occur after major project milestones, at regular intervals such as annually, or at the end of the project for legacy dissemination. By distinguishing between the technical internal tool and the accessible public version, and by embedding iterative feedback and validation, the ENFORCE Glossary will act as both a reference document and a living resource that promotes shared understanding, consistency in practice, and long-term impact.

2.2 Key Results and Terms

The scope of the ENFORCE Glossary was defined as qualitative rather than quantitative, emphasizing interpretive clarity and contextual understanding over numerical classification. This approach reflects the view that glossaries are most effective as tools for **conceptual precision and shared comprehension** rather than rigid measurement frameworks (Buljan et al. 2024). In this way, the glossary serves the scope of ensuring consistency in communication with the project's different target groups – including policymakers, institutions, and citizens – a point highlighted as a priority within the ENFORCE consortium.

Further to this, the process of the ENFORCE Glossary development resulted in the need for an extended focus on definitions related to environmental compliance assurance and stakeholder and citizen engagement, as these concepts form the foundation for linking regulatory, institutional, and societal dimensions of environmental governance. The positioning of **environmental compliance assurance as a definitional anchor** provides a clear point of reference that reflects its contextual differentiation across sociopolitical and legal systems, enforcement capacities, and governance models. At the same time, integrating stakeholder and citizen engagement ensures that participatory processes are understood not merely as supportive mechanisms but as integral to compliance outcomes, enhancing legitimacy, transparency, and accountability. The focus on such terms enables the glossary to **evolve from a static collection of definitions into a methodological tool** that promotes shared understanding across diverse contexts while guiding the development of ECCI methodologies, pilot implementation, and tailored engagement strategies for both institutional and societal actors. Overall, the ENFORCE glossary is a living document, updated biannually and published online in open-source format, designed to clarify key terms related to environmental compliance with a balance between technical precision and accessibility.

Table 2 - Glossary Key Terms

Dimension	Category	Number of Terms
Functional Area	Promotion	22
	Monitoring	28
	Enforcement	17
	ENFORCE solutions	11
Work Organisation (ENFORCE)	Project management	10
	Environmental compliance approach	14
	Data, models and tools	24

	Citizen and stakeholder engagement	15
	Knowledge and capacity building	9
	Exploitation, replication and sustainability	12
	Case studies	4
Thematic Area	Pollution	9
	Biodiversity and nature	14
	Forests and deforestation	7
	Technology and data	23
	Citizen participation	13
	Legal and enforcement	12
Total Identified Terms		78

Until Month 12 of the project, **a total of 78 terms were identified**. Of these, 22 relate to promotion, 28 to monitoring, 17 to enforcement, and 11 to ENFORCE solutions. By ENFORCE work organisation, 10 terms link to project management, 14 to the environmental compliance approach, 24 to data, models and tools, 15 to citizen and stakeholder engagement, 9 to knowledge and capacity building, 12 to exploitation, replication and sustainability, and 4 to case studies. Thematically, the glossary includes 9 terms on pollution, 14 on biodiversity and nature, 7 on forests and deforestation, 23 on technology and data, 13 on citizen participation, and 12 on legal and enforcement. All terms identified were considered relevant for the public version, with the glossary structured in a way that goes beyond a purely alphabetical arrangement or simple project-process categorisation. Instead, its organization follows a logical path of reading that not only facilitates understanding of terminology but also serves as **a practical roadmap**, supporting users in navigating concepts in relation to ECCEI-relevant processes (promotion, monitoring, enforcement, innovation within ENFORCE). *On the project's Zenodo,¹¹ it is made available the public version of the Glossary, designed to provide accessible definitions and guidance for external stakeholders while remaining consistent with ENFORCE methodological framework.*

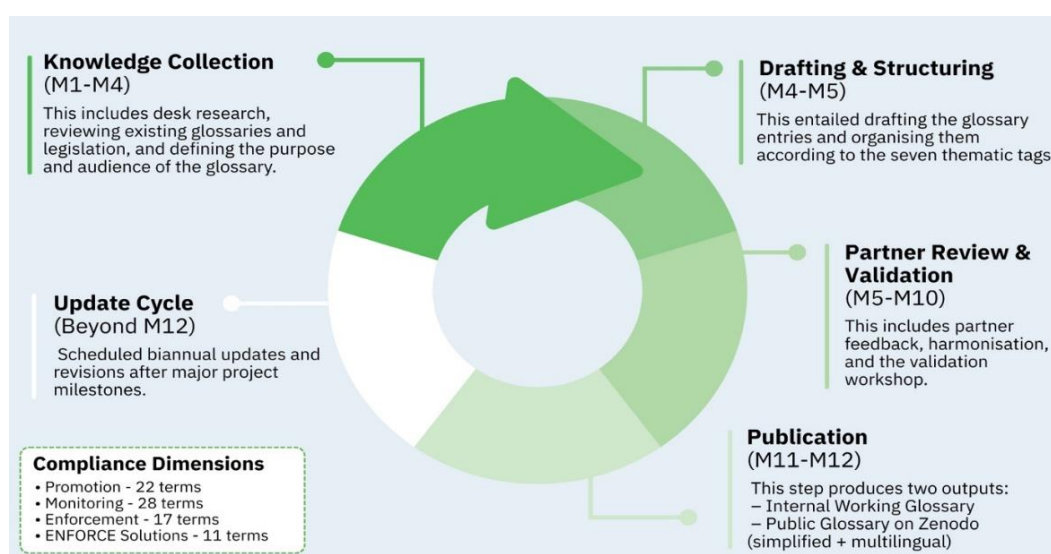


Figure 3 -
ENFORCE
Glossary
development
steps

¹¹ See <https://doi.org/10.5281/zenodo.17901267>.

Among the 78 terms in the glossary, a set of priority concepts stands out as most relevant for ENFORCE's objectives. These terms were selected for the short glossary because they capture both the functional and thematic dimensions of environmental compliance. **Compliance Assurance** provides the overarching framework linking promotion, monitoring, enforcement, and solutions into a coherent cycle, while **Environmental Crime**, **Admissible Evidence**, and **Pollution** anchor the glossary in the foundational elements of enforcement practice. **Citizen Science**, **Citizen Science for Compliance Assurance**, and **Living Labs** reflect ENFORCE's mission of linking citizens with compliance through participatory monitoring and co-creation. The innovation dimension is represented by the wise integration of **Artificial Intelligence**, **Data Dashboards**, the **ENFORCE Plaza Toolkit** and the **Data Readiness Level** framework, which show how technology supports scalable monitoring and user uptake. Finally, terms such as **Deforestation**, **Nature-Based Solutions**, **Earth Observation**, and **Biodiversity/Protected Areas** highlight the environmental domains where ENFORCE applies its case studies on pollution, biodiversity loss, and deforestation in both land and coastal zones. Together, these concepts address thematic dimensions (pollution, biodiversity, deforestation) and functional dimensions (citizens, data, innovation, enforcement), providing a concise toolkit of must-know concepts for advancing ENFORCE's work.

Table 3 - Priority ENFORCE glossary concepts organised by their function and relevance to environmental compliance

Concept	Function	ENFORCE relevance
Compliance Assurance	Overarching framework	Links promotion, monitoring, enforcement, and solutions into a coherent compliance cycle.
Environmental Crime	Enforcement foundation	Defines violations ENFORCE aims to detect and address.
Admissible Evidence	Enforcement foundation	Ensures collected information can support legal action.
Pollution	Enforcement foundation	Core thematic area relevant to ENFORCE case studies.
Citizen Science	Citizen participation	Enables citizens to contribute data and observations.
Citizen Science for Compliance Assurance	Citizen participation	Integrates citizens directly into monitoring and enforcement workflows.
Living Labs	Citizen participation	Supports co-creation and testing of compliance methods with users.
Artificial Intelligence	Innovation & digital tools	Enables scalable monitoring, analysis, and automation.
Disruptive Innovation	Innovation & digital tools	Introduces new approaches to support compliance assurance.
Data Dashboard	Innovation & digital tools	Provides visualisation and interpretation of compliance-related data.
ENFORCE Plaza Toolkit	Innovation & digital tools	Main ENFORCE solution supporting monitoring and enforcement.
Data Readiness Level	Innovation & digital tools	Assesses maturity and usability of data for compliance purposes.
User Uptake	Innovation & digital tools	Ensures tools are effectively adopted by users.

Deforestation	Environmental domain	Key environmental issue addressed in ENFORCE case studies.
Nature-Based Solutions	Environmental domain	Provides environmentally restorative approaches relevant to compliance.
Earth Observation	Environmental domain	Core data source for monitoring environmental conditions.
Biodiversity / Protected Areas	Environmental domain	Relevant to monitoring, enforcement, and case study focus areas.

The glossary is best understood as a guide to the **Environmental Compliance Process**, which in ENFORCE has four dimensions. **Promotion** brings together terms that focus on awareness, knowledge sharing, and citizen or stakeholder engagement. These highlight the participatory and capacity-building side of compliance, where the emphasis is on encouraging voluntary adherence to environmental rules. Examples include Citizen Science, Living Labs, Policy, and Capacity Building. **Monitoring** covers terms linked to tools, methods, and practices for collecting and validating data on environmental conditions and compliance. This dimension is essential for detecting breaches and generating reliable, actionable evidence. Examples include Earth Observation, Data Dashboard, Pollution, and Biodiversity. **Enforcement** relates to the legal and regulatory mechanisms that ensure compliance rules are followed. Terms here focus on accountability, evidence gathering, and prosecution where required, such as Admissible Evidence, Environmental Crime, Deforestation, and Illegal Waste. Finally, **ENFORCE Solutions** capture the innovations and tools developed within the project itself. These terms illustrate how CS, digital platforms, and disruptive innovation create new ways to promote, monitor, and enforce compliance. Examples include the ENFORCE Plaza Toolkit, Artificial Intelligence, Disruptive Innovation, and User Uptake. The glossary should therefore be read not only alphabetically but also as a step-by-step process. First comes promotion to build awareness and capacity, followed by monitoring to gather and validate evidence, then enforcement to secure accountability. ENFORCE solutions cut across all these stages, offering new methods that link citizens, data, and technology to stronger compliance outcomes.

3. The roadmap for ECCI: building a conceptual framework

3.1 Methodology for data collection across T2.1-2-3

The literature, legislation and policy review and empirical data collection in relation to environmental compliance is a transversal activity performed throughout the project, coordinated by WP2, aimed to inform the project activities. The work presented in the present deliverable builds on the foundational contribution of WP2 by developing and applying the shared framework and common terminology for ECCI. Informed by the review of literature, legislation, and policy, as well as empirical evidence, it provides a clear and accessible reference for ongoing project activities and for the implementation of the Case Studies. Using this common basis, the deliverable supports a coherent mapping of relevant academic knowledge, policies, legal instruments, and tools, enabling thus the move from general analysis to the identification and discussion of specific

legal and compliance issues in concrete contexts. In this way, the work presented here helps connect analytical insights, technological developments, and case-based practices in a way that remains grounded in real enforcement challenges. This methodological relation is illustrated extensively in **ENFORCE Deliverable 4.1** – “Initial Roadmap and monitoring plan for the activities and actions at the Case Studies” (Kofinas et al., 2025: 16-18) and will be further integrated in the future WP4 deliverables.

More specifically, the first phase of the data collection under WP2 was represented by the collection in the first 6 months of the project of diverse relevant grey literature (law, policy, media documents) and academic literature to develop a theoretical framework for the use of CS data and information in compliance assurance. This phase was covered by tasks T2.1 and T2.3. The review under T2.1 and T2.3 targeted respectively existing laws, policies, strategies, foundational concepts, reports, articles and academic literature related to environmental compliance and associated innovations. The tables compiled for the review are accessible in Open Access on Zenodo.¹²

T2.1 review was aimed at examining current policy, strategy, and underlying concepts relating to environmental compliance and innovation, drawing on research, projects, grey literature, and media sources. The review provided insights into the evolving understanding of compliance, identifying connections with disruptive innovation and showing how these developments are reflected in policy frameworks. Emphasis was placed on socio-technical innovations within ENFORCE’s three core domains (pollution, biodiversity, and illegal logging) while also considering other emerging issues. The task included an interdisciplinary analysis to define disruptive ideas and processes, with a dedicated effort to establish a shared terminology across the multiple disciplines engaged in compliance and inform the development of the environmental compliance framework together with T2.3 work.

T2.3 review in a complementary fashion to the review performed under T2.1 entailed the review of literature related to citizen science for environmental compliance. The aim of this review was to offer a detailed and nuanced understanding of applicable legislations, existing cases, and on the pertinent barriers faced by civil society, authorities and legal experts as well as innovators in the tech sector aiming to have civic data stemming from CS used for compliance. The review encompassed existing studies on CS for environmental compliance in the EU priority areas of biodiversity, pollution, farming and illegal logging. The literature review served to define the state of the art for the use of CS data and information for compliance assurance, in terms of relevant studies on existing cases, on applicable legislation, on barriers and needs, on data readiness levels.

Furthermore, under T2.3, qualitative methods have been deployed in order to gain a deeper and more detailed understanding of the key challenges faced by citizens, authorities, legal experts, researchers and innovators willing to use CS for compliance assurance. T2.3 performed a ‘**perception analysis**’ survey aimed at identifying actual and perceived barriers to the use of CS in compliance assurance, that was shared across the consortium’s networks of key stakeholders.

¹² See <https://doi.org/10.5281/zenodo.17902173>.

The text of the survey is provided as Annex II. Around 170 respondents filled the survey, from different countries, disciplines and categories of stakeholder. The survey results showing all the data collected can be found online.¹³

This data collection was enhanced by conducting **3-5 expert semi-structured interviews from partners' networks and stakeholder mapping in each of the countries** involved in the consortium, to validate the findings from desk research and from the perception survey.¹⁴ Around 40 interviews have been performed, of a duration of around 1 hour each, mostly remotely conducted. The respondents had to explicitly express their consent by reading and signing a consent form including a participant information section. The canvas for the interviews is annexed to this deliverable, together with the consent form, the template for the interview notes and the data analysis sheet (all included as Annex III). The interview was also an occasion to gather best practices useful for WP4 ENFORCE case studies, particularly in the EU's priority areas of biodiversity, pollution and agriculture.

The methodology for data collection discussed in this deliverable also includes a review of procedural law, jurisprudence and legal cases related to environmental compliance and evidence admissible in court. **This review was addressed by T2.2.** T2.2 engaged case studies in baseline research on admissible court evidence under their national laws and existing case law. The results of this research are shared in Table T2.2 (available on Zenodo)¹⁵ contains a limited amount of data compared to the other two tables, Tables T2.1 and T2.3, showing the difficulties of the consortium's partners in finding relevant resources on the use of CS in judicial instances. The table was then complemented with a desk-based review that of admissible court evidence in civil, administrative and criminal proceedings, based on EU legislation and the national laws of partners' countries. The aim of this review was to ensure that civic data would meet court standards for being used in compliance assurance proceedings. In this stage, we explored how evidence gathered through CS could be and has been delivered to environmental auditors, prosecutors, and judges in other relevant cases.

The work conducted for T2.2 will be complemented by WP4 involving case studies in the identification of legislation and policy issues to be tackled by each case study, through modelling activities and case-specific tools, collaboration with local authorities and capacity-building activities. Lastly, in a final phase the legal and policy issues identified during the case studies implementation will be the target of policy and legal recommendations. Overall, this methodological approach was developed to ensure that environmental compliance is addressed **both in a theoretical and in a practical way**, in order to enhance the contribution of CS towards this goal.

¹³ See https://it.surveymonkey.com/results/SM-JHe41LzBktgeWhhbzsXA9Q_3D_3D/.

¹⁴ Whereas in the perception survey deployed for T2.3 the gender dimension was not a specific question analysed (we decided that it was not needed for the focus of our inquiry, in light of the data minimization principle), in the follow-up interviews we ensured that both the pool of invited prospect participants and the actual people invited to the interviews were balanced in terms of gender.

¹⁵ See <https://doi.org/10.5281/zenodo.17902173>.

Table 4 - Summary of Tasks 2.1-2.3 focus and activities

Task	Focus	Key Activities / Evidence Collected
T2.1 – Literature, Legislation & Grey Literature Review		
Review of compliance concepts and how innovation (Earth Observation, digital tools, citizen-generated data) reshapes compliance assurance	Evolution of environmental compliance and its relationship with socio-technical and disruptive innovation	Identification and thematic analysis of 198 academic references & 148 grey literature documents, (including laws, policies, strategies, reports, scientific papers, and media)
Focus on ENFORCE domains: pollution, biodiversity, illegal logging		
Interdisciplinary efforts to define disruptive ideas and processes		
Establishment of a shared terminology		
Tables and data published openly on Zenodo		
T2.2 – Procedural Law, Jurisprudence & Judicial Cases		
Identification of restrictive systems (NL, partly IT) vs. broad/open systems (BE, ES, RO, GR)	Legal and evidentiary requirements for using innovative and citizen-generated data in compliance assurance	Baseline research by case study country on admissible evidence under national laws
Review of EU and national legislation related to admissible evidence		
Collection of jurisprudence relevant to citizen science evidence (limited findings)		
Desk-based completion of missing elements due to scarcity of documented CS judicial cases		
Compilation of evidence admissibility tables (civil, administrative, criminal) on Zenodo		
T2.3 – Citizen Science & Environmental Compliance		
Review of CS literature and perception survey with ~170 respondents (citizens, authorities, experts, researchers, innovators)	Barriers, opportunities, and stakeholder readiness for using citizen science in compliance assurance	Literature review of CS for environmental compliance in biodiversity, pollution, farming, and illegal logging, leading to the identification and thematic analysis of 64 documents; Review of ~170 survey responses; Deployment of 40 semi-structured expert interviews.
Identification of barriers: trust, data quality, unclear procedures, institutional readiness, legal uncertainty		
Identification of needs: training, protocols, communication channels, clearer responsibilities		
40 semi-structured expert interviews (~1 hour each) validating findings and collecting best practices		
Qualitative analysis supporting WP4 case studies		

3.2 Secondary data review across T2.1-2-3

3.2.1 Insights from the policy & law review (T2.1)

Introductory notes

Section 3.2.1 discusses the main outcomes of the review addressed in Task 2.1. and in turn informed the development of the environmental compliance framework. Sections 5, 6, and 7 further elaborate on socio-technical innovation, the roadmap, and prosecutors/citizen upskilling guides. The glossary, which provides a common language for partners and innovators, has already been presented in Section 2. As already indicated literature review was based on the identification of academic literature and grey literature (policy documents, projects and media resources) that discuss the concept of environmental compliance evolution linking it systematically with innovation. After examination and refinement of the document list, 198 academic references & 148 grey literature documents were analysed.

Academic publications were identified through Scopus using a targeted query combining terms related to environmental compliance, monitoring, enforcement, and governance, while excluding clinical and engineering contexts. Searches were restricted to relevant disciplinary fields (Environmental Science, Business Management and Accounting, Earth and Planetary Sciences, Economics, Econometrics and Finance, Decision Sciences, Agricultural and Biological Sciences, and the Social Sciences) in order to ensure conceptual and methodological alignment with the research questions, but applied without date or geographical filters. This resulted in 168 documents, supplemented by approximately 30 additional publications identified through Google Scholar and citation tracking. **The final academic corpus consists of 198 items**, predominantly journal articles, with additional conference proceedings and book chapters. Geographically, the corpus spans EU-focused studies, non-EU country analyses, and comparative or general work. Methodologically, it includes empirical research, reviews, conceptual analyses, case studies, modelling studies, and mixed-method contributions.

To situate academic insights within the realities of policy implementation and emerging innovation, the corpus was expanded with grey literature, project outputs, and media sources. These were collected through systematic searches of EUR-Lex, European Commission websites, national environmental authorities, and EU-funded project repositories, using keywords aligned with the academic search. Media sources were identified through major European news platforms, focusing on documented compliance breaches and emerging citizen-led monitoring practices. **This practice-oriented dataset comprises 148 items: 128 grey literature documents, 12 project outputs, and 8 media sources.**

Together, the 198 academic publications and 148 non-academic sources were **analysed in relation to the research questions** guiding this deliverable, covering: the evolution of environmental compliance from sanction-based to hybrid models; the role of EU regulatory mechanisms in driving disruptive change; the impact of socio-technical innovation on monitoring and enforcement; the behavioural effects of public participation; the identification of transferable

best practices; and the relevance of thematic domains such as pollution, biodiversity, and illegal logging.

Environmental compliance has undergone **significant conceptual and operational transformation** over the past several decades. The academic literature captured in this dataset traces this evolution, documenting a shift from traditional, sanction-centred enforcement models toward hybrid governance arrangements that integrate behavioural insights, socio-technical innovation, and participatory forms of monitoring. Across the major environmental domains addressed in this deliverable – pollution, biodiversity, and forestry – the literature illustrates also how compliance challenges arise while emerging tools, institutional arrangements, and collaborative practices are being more prominent in regulatory performance. The results presented in the following sections build on this foundation, moving from conceptual developments in the scholarship to the ways these ideas inform contemporary policy instruments and ultimately manifest in compliance practice.

Environmental Compliance as an evolving concept: conceptual considerations

A first aspect addressed was the **theoretical dimension of environmental compliance**, examined as an evolving concept that continues to adapt in response to changing environmental, legal, and social conditions. The review highlighted how compliance has moved beyond a narrow legalistic understanding to encompass broader perspectives that integrate governance, citizen participation, and innovation. This evolution reflects the need to balance enforcement with promotion and monitoring, while also embedding compliance within sustainability transitions and socio-technical innovation.

Early contributions in the dataset, such as Heyes (2000), typically conceptualise compliance within a deterrence and monitoring framework. Compliance behaviour is understood as a function of regulatory pressure, inspections, and sanctions – mechanisms designed to increase the expected cost of non-compliance. These studies reflect a predominantly command-and-control paradigm, in which regulators act as external monitors seeking to correct information asymmetries between polluters and authorities.

By the mid-2000s, scholarship begins identifying the **limitations of purely punitive models**. Vandenberg (2003) provides a critical shift by embedding compliance within social and organisational contexts, showing how informal norms, peer influence, and perceptions of legitimacy shape environmental behaviour. This work begins the transition toward behaviourally informed compliance, highlighting that legal incentives interact dynamically with human decision-making and institutional culture.

In the 2010s and early 2020s, the literature increasingly frames **compliance as a governance process** rather than a regulatory outcome. Studies such as Uhlmann (2009) and Markowitz and Gerardu (2012) emphasise the strengthening role of environmental crime enforcement, transnational cooperation, and judicial capacity-building. Meanwhile, works such as Kingston et al. (2021) and Alblas (2018) expand this notion by focusing on the effectiveness of EU nature governance, illustrating that compliance depends on multi-level governance structures,

accountability mechanisms, and public participation. Recent bibliometric analyses, including Chi and Yang (2024), reveal that environmental compliance research has become **increasingly interdisciplinary**, drawing from law, economics, sociology, and data science. This confirms the field's conceptual transformation from compliance as rule-following to compliance as systemic governance, integrating institutions, technologies, societal actors, and ecological outcomes.

In this view, compliance encompasses legal conformity, institutional stewardship, citizen participation, and alignment with global sustainability frameworks such as the United Nations Sustainable Development Goals (UN, 2015) and the UN General Assembly's recognition of the right to a clean, healthy, and sustainable environment (UNGA, 2022). The review indicated that compliance is shaped not only by regulatory enforcement but also by socio-technical innovation, governance capacity, and societal dynamics. Definitions of compliance, however, remain **fragmented across disciplines, sectors, and jurisdictions**, leading to **inconsistencies in implementation, monitoring, and evaluation** (Chi & Yang, 2024; Fitzmaurice, 2018). Structural differences among states further reinforce this fragmentation, as regulations are often modelled on regional frameworks (Rogers, 2020), but enforcement tends to be reactive, triggered by crises such as pollution disasters rather than preventive (Bar et al., 2024). Rapid urbanization, industrialization, and population growth intensify these challenges, while institutional capacity often lags behind the need for strong enforcement (Efthymiou et al., 2025).

Technological and societal transformations add further complexity. Advancements in environmental technologies, monitoring tools, and cleaner production support energy transition and efficiency (Awewomom et al., 2024), yet disruptive innovations and globalization also generate novel risks that complicate regulatory oversight (Zeng & Punjwani, 2025). **The relationship between compliance and innovation is not linear**: environmental regulations may initially constrain firms, but beyond a certain threshold they can stimulate ecological and green innovation (Liu et al., 2021; Tran-ham et al. 2024). Compliance behaviour is also shaped by both internal drivers – such as human capital – and external pressures, including political forces, social capital, and market dynamics (Lan & Munro, 2013; Wu, 2009). Importantly, firms do not always comply at the minimum required level: some strategically ‘over-comply’ to appeal to consumers or pre-empt stricter regulation, while others risk non-compliance when penalties are outweighed by economic gains (Wu, 2009). This is an important aspect to be considered in orienting CS to foster compliance assurance.

Social and cultural factors reinforce these dynamics. Civil society participation, public environmental awareness, and social norms consistently improve compliance outcomes, especially where governance frameworks are effective (Abdulla & Serikbayeva, 2025). Professional norms and peer benchmarking can also induce compliance even in the absence of strict regulation (Earnhart & Friesen 2024; Vandenbergh, 2003). These developments broaden the scope of compliance into **participatory governance**, where mechanisms such as CS, participatory monitoring, and social license to operate enhance transparency and legitimacy (Burch et al., 2025; INECE, 2009). At the same time, corporate motivations for “beyond

compliance” behaviours – whether driven by market reputation, stakeholder demands, or moral obligations – highlight the complexity of incentives at play (Fox et al., 1996; Truong et al., 2025).

Despite significant advances, **gaps remain**. Much of the research still focuses on measurable pollutants like air and water quality, with less systematic attention to biodiversity loss or renewable energy siting (Barr et al., 2025) and to broader impacts on ecosystem services. The field of enforcement itself is divided between deterrence-based and cooperative models, with limited integrative approaches that incorporate behavioural, social, and economic dimensions (Heyes, 2000; Uhlmann, 2009; Biancardi et al., 2024). While theories such as the Porter Hypothesis, Legitimacy Theory, Institutional Theory, and Deterrence Theory (Chi & Yang, 2024) have expanded understanding, empirical limitations constrain analysis across contexts. In sum, environmental compliance is neither a static legal construct nor a simple matter of rule-following. It is a dynamic governance process, shaped by regulation, institutional capacity, innovation, civil society engagement, and social norms, yet hindered by fragmented definitions, uneven enforcement, and gaps in empirical integration. Advancing the field requires holistic conceptualization, deeper examination of its interaction with innovation and governance, and policies that balance deterrence, cooperation, and normative change to foster sustainability, resilience, and collective stewardship.

To deepen understanding, it is necessary to clarify the conceptual foundations of environmental compliance and environmental compliance enforcement, as their interpretation varies across disciplines, jurisdictions, and regulatory contexts. Jones (2011) critiques the tendency to equate compliance with narrowly defined technical requirements, arguing that this reductionist view constitutes an abdication of responsibility. Instead, genuine compliance requires designing and managing landscapes in ways that conform to ecological and geomorphological principles, thereby enabling the development of self-sustaining ecosystems. From this perspective, **compliance involves aligning with environmental systems** rather than merely acquiescing to human-made rules.

A good practice principle highlighted in literature is that compliance systems function most effectively when they **integrate legal clarity with robust monitoring capacity, behavioural insight, and mechanisms for participatory accountability**. Contemporary scholarship consistently demonstrates that regulatory instruments alone are insufficient unless complemented by systems that detect non-compliance, understand the incentives and constraints shaping regulated actors’ behaviour, and incorporate citizens as contributors to oversight and information flows. Within this literature, transparency and legitimacy emerge as critical predictors of compliance performance: when regulatory processes are visible, evidence is trustworthy, and decision-making is perceived as fair, both institutional actors and the regulated community exhibit higher levels of cooperation and adherence.

Related to this argument is the consideration of **CAT**, which according to Laughlin (1999: 73) is: “A critical understanding of the role of accounting processes and practices and the accounting profession in the functioning of society and organisations with an intention to use that understanding to engage (where appropriate) in changing these processes, practices and the

profession". Laughlin (1999) describes CAT as follows. First, CAT is always contextual that as a profession and practice has social, political and economic consequences in society and needs to be critically analysed, understood and changed in this context.

The second is that the process of evaluation of a practice leads to **engagement** which in turn leads to a **change** in the **understanding** of the practice. The role of interested communities in steering this change is where additional research in CAT is most needed. Similarly, it is key to clarify what is the critical area of environmental compliance that one wants to evaluate, engage with and change. Thirdly, CAT aims to examine the **functioning** of the accounting (and environmental compliance) profession, practices and processes at the 'macro' (societal, government, regulatory, professional) as well as at the 'micro' (institutional and organisational) level. In developing an environmental compliance roadmap, the focus of CAT on **reflexive learning** can guide partners, citizens, innovators and other interested users in the ENFORCE project to leverage CS potential to evaluate and engage with, and where necessary, advocate for change to, the processes, practices, and people involved with compliance assurance.

At the international level, compliance has been widely debated within the frameworks of environmental treaties, governance, and sustainability norms. Legally, compliance has been defined as the degree to which behaviour aligns with environmental laws, treaties, and standards. Fitzmaurice (2018) emphasizes that **compliance is fluid and context-dependent**, shaped by diverse national legal systems, socio-political contexts, and enforcement capacities. By contrast, enforcement refers to the means through which compliance is compelled. It encompasses both formal and informal mechanisms aimed at deterring violations and punishing infractions. Whereas compliance frameworks are generally cooperative and oriented toward achieving environmental goals, enforcement systems tend to be more punitive, emphasizing retribution and deterrence (Fitzmaurice, 2018).

These conceptual distinctions are critical, as the drivers of compliance behaviour are complex. Some actors comply due to fear of legal sanctions or reputational damage, while others pursue voluntary measures to achieve compliance as part of sustainability strategies or to secure the feasibility of environmental measures in business and society (Burch et al., 2025). As noted above, in certain contexts, firms even engage in over-compliance – either to appeal to environmentally conscious consumers or to pre-empt stricter regulations (Wu, 2009). Conversely, **non-compliance may arise from limited awareness, inadequate capacity to comply and/or inadequate ability to ensure compliance** from authorities, or cost-benefit calculations where violations appear less costly than compliance especially for large corporations (Lan & Munro, 2013; Biancardi et al., 2024).

Based on the aforementioned contributions, **environmental compliance** in ENFORCE is understood as the adherence of individuals, organizations, or states to environmental laws, treaties, and standards, while also encompassing proactive and voluntary measures that mitigate ecological harm, foster innovation, and promote sustainability. **Environmental enforcement**, in contrast, is addressed as the application of legal instruments, sanctions, and institutional mechanisms designed to compel compliance, deter violations ex ante, and remediate

environmental damage ex post, after an actual non-compliance occurred. Clarifying these concepts is essential, since the effectiveness of environmental governance depends not only on the presence of rules but also on **the interplay of voluntary action, participatory engagement, regulatory enforcement, and the legitimacy of environmental norms** as the evolution of the compliance concept indicates.

Links to disruptive innovation

Reflecting conceptual considerations, the dataset highlights a growing interest in how certain regulatory mechanisms reshape compliance behaviour in ways that could be considered structurally disruptive. For example, Earnhart and Friesen (2024) examine how professional norms within industries may override or reshape regulatory expectations, indicating that disruption may occur “from within” institutions through evolving professional cultures rather than only through legislation. Similarly, research by Kingston et al. (2021) on EU nature governance demonstrates that compliance is strengthened when regulatory systems undergo democratisation – expanding access to information, consultation, and redress mechanisms. Governance reforms that enhance the role of NGOs, scientific bodies, and local communities are therefore inherently disruptive, because they shift authority away from centralised enforcement bodies and toward distributed networks of actors.

Pinheiro et al. (2024) contribute to this discussion by examining how compliance and innovation interact in organisational settings. They find that regulatory frameworks can stimulate innovation when compliance obligations introduce new performance expectations or risk scenarios. In such cases, disruption occurs when firms embed compliance into strategic planning, technological development, and operational redesign. A key good practice emerging from the literature is that regulatory disruption is most effective when it fosters organisational learning, transparency, and adaptive governance, rather than relying solely on the escalation of penalties or coercive measures.

In the dimension of Compliance monitoring, a significant body of literature in the dataset addresses the role of technological innovation in modern compliance systems. Benami, Ho and McDonough (2020) demonstrate the potential of machine learning to improve environmental inspection and enforcement by identifying atypical patterns in emissions data. Such models enable regulators to transition from periodic inspections toward predictive, high-frequency monitoring. Likewise, Allena (2019) argues that blockchain systems offer a tool for improving traceability and transparency, especially in contexts where supply-chain complexity limits the effectiveness of traditional compliance instruments. Luna et al. (2024) support this finding in the aquaculture sector, where blockchain-based traceability systems not only reduce fraud but also change how actors perceive their compliance obligations by introducing immutable and verifiable accountability.

On the social side of innovation, Loisel et al. (2024) show how citizen-generated water quality data can reliably support regulatory monitoring. Their work highlights that innovation is not limited to digital technologies; it also includes new forms of socio-technical co-production, where

communities contribute meaningful evidence to compliance systems. Likewise, a recurring theme in the dataset is the importance of public participation in shaping environmental compliance. Studies such as Cook et al. (2016) and Collins et al. (2023) document how catchment partnerships in the UK integrate stakeholders into environmental governance, resulting in improved monitoring, priority-setting, and conflict resolution.

Kingston et al. (2021) similarly underscore the significance of democratisation in nature governance, showing that participatory processes strengthen compliance by increasing both the legitimacy and the practical feasibility of implementation. Participation therefore functions not merely as an ethical principle but as a functional component of environmental regulation. Furthermore, Facchinelli et al. (2023) provide a striking example from the Ecuadorian Amazon, where participatory evidence gathering led to judicial action against harmful environmental practices. Their findings indicate that citizen involvement can directly influence enforcement and remediation.

The literature thus demonstrates that compliance systems benefit most when technological tools augment rather than replace human oversight. Hybrid models that integrate AI-driven analytics, community-generated environmental data, and traditional regulatory supervision consistently yield more robust and timely monitoring outcomes. Within such models, technology enhances detection and analysis capacities, while human judgement, contextual understanding, and institutional authority ensure appropriate interpretation and action. Effective compliance frameworks therefore move beyond ad hoc engagement to institutionalise public participation, establishing procedures through which community-generated evidence becomes admissible, traceable, and operationally meaningful within administrative and enforcement decision-making.

In the policy level traditional monitoring systems - based on periodic inspections and limited sampling - have been supplemented or replaced by continuous, high-resolution data infrastructures. Remote sensing technologies monitor deforestation, landfills and marine litter; AI-assisted analytics support anomaly detection and targeted inspections; blockchain mechanisms facilitate traceability in supply chains; digital twins provide predictive modelling for environmental risk; and citizen sensor networks generate granular air and water-quality data. Projects documented in the grey literature illustrate these shifts vividly: Belgium's CurieuzenAir initiative demonstrates the policy relevance of large-scale citizen-generated air-quality datasets; Spain's marine litter monitoring system under the Marine Strategy Framework Directive translates EU obligations into advanced, multi-parameter data collection; Italy's ARPA-led monitoring campaigns around Malagrotta and other industrial areas show how mobile labs and continuous sensors reshape regulatory responses; and UK watershed monitoring initiatives reflect hybrid models that combine state oversight with community-generated evidence. These technologies expand the epistemic base available to regulators but also recalibrate expectations regarding what constitutes adequate monitoring and timely enforcement.

Alongside technological advances, the role of public participation has become increasingly central to how environmental compliance functions today. The Aarhus Convention and its implementation in EU law have firmly established three procedural rights – access to

environmental information, participation in decision-making, and access to justice – as essential elements of environmental governance. In practice, however, contemporary participation goes far beyond these formal requirements. CS projects, investigative journalism, community monitoring efforts, and strategic litigation now operate as practical tools of accountability, generating information that can reveal environmental problems, highlight gaps in official oversight, and prompt action from authorities. These forms of public engagement are no longer peripheral. They are becoming embedded parts of compliance systems, contributing to greater transparency, stronger legitimacy, and more responsive regulatory behaviour.

Links to policy development

This section extends the conceptual discussion by tracing how compliance matured in international and EU policy. The evolution of environmental compliance within the European Union reveals a marked shift from a predominantly formalistic and transposition-oriented model of governance to an increasingly sophisticated, performance-driven and participatory regulatory system. In the earlier phases of European environmental policy, compliance was largely conceptualised as the incorporation of EU directives into domestic legal frameworks, supported by periodic reporting obligations and enforced primarily through violation procedures. This reactive, litigation-centred model positioned compliance as a legal endpoint – confirmed when transposition was achieved or when non-compliance was sanctioned – rather than as a continuous process of institutional learning and adaptive implementation.

More specifically, early international instruments set the tone for compliance as both facilitative and enforceable. CITES (1973) introduced targeted trade suspensions to deter non-compliance, while the Montreal Protocol (1987) established a formal non-compliance procedure through an Implementation Committee that paired technical assistance with credible trade restrictions (CITES Secretariat, 2022; Ozone Secretariat, 2023). By the late 1990s, the Kyoto Protocol (1997) created a two-branch system – Facilitative and Enforcement – marking a clear architecture for guidance and sanctions, and the Aarhus Convention (1998) opened compliance review to the public, embedding participation within enforcement pathways (UNFCCC, 1997; UNECE, 2018).

Within the EU, **foundational directives in the 1990s–2000s reframed compliance as a comprehensive legal duty**. Core texts include the Habitats Directive 1992/43/EEC, Directive 94/62/EC on packaging waste, Directive 99/31/EC on landfills, The EU Water Framework Directive (WFD) 2000/60/EC and related Directives (Directive 2006/7/EC concerning the management of bathing water quality, Directive 2008/56/EC, the Marine Strategy Framework Directive (MSFD) that established a framework for member states to achieve Good Environmental Status in their marine waters, Directive 91/271/EEC concerning waste water treatment (now updated in the Urban Waste Water Directive- Directive (EU) 2024/3019, Directive 2006/118/EC (updated 2014/80/EU), about protection of groundwater from pollution and deterioration), Directive 2001/42/EC on strategic environmental assessment, Directive 2004/35/EC on environmental liability, the Waste Framework Directive 2008/98/EC, the Environmental Crime Directive 2008/99/EC, the Birds Directive 2009/147/EC, and the Industrial Emissions Directive 2010/75/EU. These instruments operate within a robust enforcement system under Articles 258–

260 TFEU, with the Commission as “guardian of the Treaties” and the CJEU confirming breaches where needed (e.g., illegal logging litigation such as C-441/17).

Over the past decade, however, the EU has articulated a substantially different vision of compliance, one grounded not only in legal conformity but in measurable environmental performance, administrative capacity-building and systemic governance reform. Instruments such as the Environmental Implementation Review (EIR), the Action Plan on Environmental Compliance and Governance and the Zero Pollution Strategy have reconceptualised compliance as an ongoing, multi-level process embedded within the broader objectives of sustainability, climate neutrality and ecological resilience. These frameworks emphasise preventive governance, risk-based inspections, inter-agency coordination and the mobilisation of both public and private actors.

This new phase from the 2010s integrated compliance with sustainability, circular economy, and supply-chain accountability. Key measures include the EU Timber Regulation 995/2010, the Medium Combustion Plants Directive 2015/2193, the Circular Economy amendments in Directive 2018/851 which intervened on the EU’s Waste Framework Directive 2008/98, establishing the principle of Extended Producer Responsibility (EPR) which shifted the environmental and economic burden of waste management from public authorities to producers, the Single-Use Plastics Directive 2019/904, the Drinking Water Directive 2020/2184, the Deforestation-free Products Regulation 2023/1115, the Nature Restoration Law (2024), the Ambient Air Quality Directive 2024/2881, the Corporate Sustainability Due Diligence Directive 2024/1760, and the F-gases Regulation 2024/573. Strategic frameworks - the 2018 Action Plan on Environmental Compliance and Governance, the European Green Deal (2019), the Zero Pollution Action Plan (2021), and the Environmental Implementation Reviews (2019, 2022) – shifted the centre of gravity from reactive enforcement to performance-oriented, system-wide governance.

These developments are further intensified by the **emergence of a new generation of EU instruments that introduce disruptive regulatory logics extending far beyond traditional sector-based environmental directives.** Regulations such as the Corporate Sustainability Due Diligence Directive (Directive (EU) 2024/1760), the Deforestation-Free Products Regulation (Regulation (EU) 2023/1115), the Nature Restoration Law (2024), and the revised Ambient Air Quality Directive (Directive (EU) 2024/2881) shift compliance obligations across entire supply chains and value systems, implicating corporate governance, international trade, financial oversight, and spatial planning. Their disruptive quality derives from both this broadened regulatory scope and the redistribution of accountability among state authorities, private-sector actors, and civil society. Member States are required to build new monitoring architectures, strengthen cross-agency enforcement systems, and integrate transparency and disclosure duties into daily administrative practice. National responses (relevant to ENFORCE case studies) already illustrate the structural impact of this shift: Greece’s revisions to licensing and permitting embed EU compliance obligations into economic decision-making; Italy’s amendments to its environmental code demonstrate the layered interaction of EU directives, national decrees, and

judicial doctrine; Romania's forestry reforms align domestic monitoring with EU and global traceability requirements; Spain's marine and waste legislation reflects the cascading influence of EU law across regional and municipal levels; Belgium's PFAS-related initiatives exemplify how environmental health crises can recalibrate national enforcement priorities; Netherlands' advanced risk-based and data-rich monitoring systems, integrating remote sensing and participatory reporting into environmental supervision. Beyond the EU, the United Kingdom has reconfigured its post-Brexit environmental governance through the Office for Environmental Protection (OEP), strengthening oversight and investigatory powers while adopting compliance approaches closely aligned with EU principles, demonstrating convergence despite regulatory divergence.

In parallel, tools and participation now anchor day-to-day compliance practice, reinforcing these regulatory transformations through socio-technical capacity. Blockchain pilots in aquaculture and fisheries show how tamper-resistant ledgers can close persistent traceability and fraud gaps (Luna et al., 2024). The European Commission's Citizen Science Guidance and inventories position the public as structured data providers and accountability partners (European Commission, 2020), while recent proposals for an EU Expert Committee on CS underscore the momentum toward institutionalising public participation within environmental governance (AURORA et al., 2024). Additionally, the EU Guidance on Environmental Compliance Assurance provides inspectors, police, customs authorities, and prosecutors with coordinated investigative and enforcement methodologies, supporting more coherent and prevention-oriented action against environmental crime (European Commission, 2021). These developments are examples of how regulatory reform, socio-technical innovation, and participatory practices are increasingly interwoven as mutually reinforcing pillars of a modern environmental compliance regime.

Overall, international regimes moved from predominantly sanction-based models (Montreal, Kyoto) to hybrid, facilitative, and participatory arrangements (Aarhus and later treaty practice). The EU model complements this with binding legislation, infringement procedures, CJEU case law, strategic implementation reviews, and rapidly evolving digital and participatory instruments. The trajectory aligns with the conceptual framing from the previous section: **compliance now sits at the intersection of legal enforceability, institutional capacity, corporate due diligence, human rights, socio-technical innovation, and citizen engagement** – thereby functioning as a pillar of broader sustainability governance rather than a narrow box-ticking exercise.

The **recent advisory opinion of the International Court of Justice (ICJ)** on climate change represents a crucial step towards consolidating the legal responsibility of States in relation to climate change and the protection of human rights. By recognising climate change as an existential threat and affirming that states have **positive obligations of prevention, mitigation and cooperation** based on multiple sources of international law, the Court is helping to redefine the parameters of international climate action (International Court of Justice, 2025). This approach has a **spillover effect on domestic and transnational practices**, strengthening environmental

compliance and **legitimising the actions of national courts and affected communities** in demanding the effective implementation of environmental and climate law.

A prime example is **the case of the Mecheros in the Amazon Rainforest**, where the Nueva Loja Court's ruling of 2021 banning oil-related gas flaring is also based on scientific evidence co-produced through Extreme CS processes. Research has shown that almost all of the 295 active combustion sites affect the health of approximately 100,000 people and contribute significantly to greenhouse gas emissions, demonstrating the inextricable link between local pollution and the global climate crisis (Facchinelli et al., 2023). In this sense, **international jurisprudence and participatory practices converge in strengthening compliance** as a dynamic and multi-level tool, capable of translating the principles of international law into concrete obligations of environmental protection and climate justice.

Sectoral considerations as regards logging, biodiversity and pollution

The review of compliance and innovation is revisited through the three sectors that constitute the core focus of the ENFORCE project (illegal logging, biodiversity conservation, and pollution control). These domains provide concrete illustrations of how compliance frameworks are evolving, how disruptive and socio-technical innovations are reshaping enforcement, and how policy shifts enable or constrain these transformations.

Logging and Forest Governance

Illegal logging remains one of the most persistent challenges for environmental compliance. Within the EU, the EU Timber Regulation (995/2010) and, more recently, the Deforestation-free Products Regulation (2023/1115) provide binding frameworks obliging operators to ensure legality and sustainability of wood and related commodities. National frameworks, such as the Romanian Forestry Code (2024), show how Member States are adapting EU obligations to domestic contexts. However, research highlights how corruption and weak institutional capacity (Bouriaud, 2014) undermine enforcement. The project revisits logging because it offers a space where digital innovation (e.g. blockchain for timber traceability (Luna et al., 2024) and citizen engagement tools can directly address compliance deficits. Logging therefore represents a testbed for blending legal enforceability with disruptive innovations that increase transparency, accountability, and societal participation.

Forestry and illegal logging research spotlights the interaction between environmental crime, corruption control, property rights and trade governance. Bouriaud (2005, 2014) examines how poverty, institutional capacity and corruption shape illegal logging in Central and Eastern Europe and Romania. Duchelle et al. (2014) and subsequent REDD+-related work link tenure reform, compliance and incentive schemes in the Brazilian Amazon. More recent work on deforestation and European regulatory extraterritoriality (Mata Diz et al., 2024; Massoca & Brondízio, 2022; Pires & Steinke, 2022; Arruda et al., 2025) shows how supply-chain regulation, spatial targeting and criminal enforcement interact. In this domain, innovation is driven by digital traceability systems, satellite-based deforestation monitoring, transparency mechanisms and cross-border legal frameworks.

Biodiversity Conservation

Biodiversity is central to compliance because it cuts across ecological integrity, social legitimacy, and international obligations. The Birds Directive (2009/147/EC) and the Habitats Directive have long formed the backbone of EU biodiversity law, with infringement proceedings (e.g. C-441/17 on Białowieża Forest) affirming their binding force. Yet biodiversity decline continues, prompting the adoption of transformative instruments such as the Nature Restoration Law (2024), which imposes proactive restoration duties on Member States.

The project highlights biodiversity as a sector where participatory innovations (e.g., citizen science for monitoring species and habitats, European Commission, 2020) and policy experimentation (e.g., agri-environmental schemes in the Netherlands, Alblas & van Zeben, 2023) can redefine compliance. Rather than focusing solely on prohibitions and sanctions, biodiversity compliance is increasingly linked to collaborative governance and ecosystem restoration, making it a key arena for testing integrated compliance frameworks.

In the field of biodiversity and nature governance, compliance research focuses more strongly on legitimacy, accountability and institutional complexity. Kingston (2021), Kingston et al. (2022) and Kingston & Wang (2023) analyse how democratic governance, public participation and rule design affect compliance decisions in EU nature law. Alblas (2018) and Alblas & van Zeben (2023) explore conflicting objectives and the implementation of agri-environmental schemes, revealing tensions between ecological objectives, agricultural policy and enforcement capacities. These contributions foreground the need for multi-level governance arrangements, integrated ecological data, and participatory decision-making frameworks capable of dealing with uncertainty and trade-offs. Here, innovation often takes the form of governance experiments, stakeholder platforms, new indicators for ecological status and rule effectiveness, and more transparent accountability mechanisms.

Pollution Control

Pollution governance illustrates the trajectory from traditional permitting systems toward integrated, innovation-driven compliance cultures. Foundational directives such as the Landfill Directive (1999/31/EC) and the Industrial Emissions Directive (2010/75/EU) established binding monitoring and liability standards. These have been complemented by newer measures such as the Medium Combustion Plants Directive (2015/2193), the Drinking Water Directive (2020/2184), and the Ambient Air Quality Directive (2024/2881), all tied into the Zero Pollution Action Plan (2021).

Furthermore, also the Urban Wastewater Directive (2024/3019) is worth citing in relation to pollution control. This directive is a key instrument for achieving the Zero Pollution Action Plan in terms of water related objectives. The directive establishes stricter requirements for urban wastewater treatment (such as micropollutant treatment and nutrient recovery) to ensure that water pollution is reduced to levels that are not harmful to health and the environment.

Pollution is revisited in the project because it demonstrates how technological innovations (e.g., machine learning for compliance detection, Benami et al. 2020), CS monitoring networks

(CurieuzenAir, 2022; Collins et al., 2023), and data-driven enforcement tools expand the reach of regulatory agencies. At the same time, persistent cases of non-compliance (e.g., Italy’s landfill management, C-323/13) reveal the continued importance of judicial enforcement as the “last line” of compliance assurance.

Pollution-related studies emphasise the need for continuous and often high-frequency monitoring, as well as the integration of predictive and spatial analytics. Work on regulatory enforcement and emissions control (e.g. Heyes, 2000; Söderholm et al., 2019; Wu, 2009; Chugg et al., 2022; Goldberg et al., 2024) demonstrates how conventional inspection regimes are increasingly complemented by remote sensing, automated detection and risk scoring. Studies on water and industrial pollution (Haque, 2017; Sakamoto et al., 2019; Toller et al., 2022; Chou et al., 2025) underline the importance of reliable data infrastructures and targeted inspections. Loiselle et al. (2024) show how citizen scientists can fill knowledge gaps in phosphate pollution dynamics in rural catchments, while Facchinelli et al. (2023) use participatory approaches and health risk analysis to challenge gas flaring in the Ecuadorian Amazon. In this domain, compliance innovation is closely tied to dense monitoring networks, remote sensing, algorithmic tools and community observations.

Environmental Compliance Assurance: Lessons from Research Projects, Communities, and Media

Research projects have advanced digital and data-driven tools for monitoring and enforcement. The Stanford Institute for Economic Policy Research explored the use of machine learning for compliance detection (Benami et al., 2020), while blockchain pilots in aquaculture (Luna et al., 2024) and broader governance contexts (Allena, 2019) demonstrated how traceability and fraud prevention can improve compliance credibility. Other comparative research, such as Kingston et al. (2021) on the democratisation of EU nature governance, highlighted the importance of public participation in strengthening compliance outcomes.

Community-driven projects have also provided good practices. EU-funded initiatives like AURORA,¹⁶ COMPAIR,¹⁷ and SOCIO-BEE¹⁸ promoted CS as a compliance support mechanism, feeding community-generated data into EU-level regulatory processes. In the UK, the Catchment Systems Thinking Cooperative (CaSTCo)¹⁹ and Catchment Based Approach (CaBA)²⁰ networks mobilised volunteers and stakeholders to co-produce water quality monitoring data, strengthening both enforcement and local legitimacy. In Brussels, the CurieuzenAir project²¹ engaged 3,000 citizens to map nitrogen dioxide pollution at an unprecedented spatial scale, providing actionable evidence for city and EU compliance frameworks.

¹⁶ See <https://www.aurora-h2020.eu/>.

¹⁷ See <https://cordis.europa.eu/project/id/101036563>.

¹⁸ See <https://cordis.europa.eu/article/id/451850-tapping-into-the-hive-mind-to-address-air-pollution>.

¹⁹ See <https://castco.org/>.

²⁰ See <https://catchmentbasedapproach.org/>.

²¹ See <https://curieuzenair.brussels/en/home/>.

Media and civil society have been critical in revealing enforcement gaps and mobilising compliance responses. The BBC's coverage of Romanian protests (2019) over illegal logging and related violence underscored the role of public pressure in pushing authorities toward stricter forest governance. Similarly, European NGOs and media outlets have raised concerns over the EU Omnibus Package (2025), warning that it could dilute corporate responsibility rules on due diligence and sustainability reporting (Forbes 2025; ECCJ 2025). Local cases, such as investigative coverage of the Malagrotta landfill crisis in Italy (which also triggered an EU's infringement procedure against Italy²²), show that when the state fails to adequately enforce laws or regulations, non-state actors and particularly local communities and the media can compel organizations or individuals to comply with expected standards.

All in all compliance assurance appears to be not only a regulatory process but also a dynamic interplay of research innovation, grassroots monitoring, and public accountability. This creates fertile ground for linking the project's sectoral foci (logging, biodiversity, and pollution) with broader societal innovations in compliance.

Lessons Learned from the Review towards the Development of an Environmental Compliance Conceptual Framework

Overall, the academic literature in the dataset reveals a rich and evolving understanding of environmental compliance. It moves beyond simple models of enforcement and deterrence toward a multilayered system incorporating governance, behavioural insights, digital innovation, and public participation. The emergence of hybrid governance models, disruptive regulatory mechanisms, and socio-technical systems signals not only conceptual growth but also practical opportunities for designing more responsive, adaptive, and equitable compliance frameworks. Ultimately, the literature illustrates that environmental compliance is not a static endpoint but a dynamic process – one that requires continual adaptation, technological integration, and community engagement. In parallel, policy analysis focused on thematic compliance domains – pollution, biodiversity and illegal logging – provide concrete frameworks through which the evolution of both EU-level and national-level systems becomes analytically visible. Pollution cases across Italy, Belgium and Greece expose the vulnerabilities of legacy monitoring systems while demonstrating how crisis conditions catalyse regulatory reform. Biodiversity governance, shaped by Natura 2000 requirements and reinforced through the Nature Restoration Law, reveals the need for cross-sectoral coordination and new data infrastructures. Illegal logging in Romania exemplifies the intersection of environmental crime, trade governance, corruption control and digital traceability. These thematic areas function both as stress tests and as drivers of innovation in compliance governance.

²² See https://ec.europa.eu/commission/presscorner/detail/en/ip_13_250.

Table 5 - Summary of Academic Literature Review for Environmental Compliance Findings

Research Question	Representative Academic Literature (From Dataset)	Key Insights Identified in Literature	Good Practices Emerging	Thematic Area
Evolution of environmental compliance internationally and in the EU	Heyes (2000); Vandenberg (2003); Uhlmann (2009); Markowitz & Gerardu (2012); Kingston et al. (2021); Alblas (2018); Chi & Yang (2024)	Compliance has moved from deterrence and enforcement toward behaviourally informed, participatory, and multi-level governance models. Social norms, legitimacy, and institutional capacity increasingly shape compliance outcomes.	Combine formal enforcement with behavioural approaches; strengthen legitimacy and institutional transparency; promote multi-level governance coordination.	Pollution; Governance; Biodiversity
Disruptive EU regulatory mechanisms shaping compliance systems and market behaviour	Earnhart & Friesen (2024); Kingston et al. (2021); Pinheiro et al. (2024); Alblas & van Zeben (2023)	Disruption occurs when regulations reshape organisational incentives, professional norms, and governance structures. Democratisation and accountability reforms in EU nature governance are particularly impactful.	Link compliance obligations to organisational learning; embed stakeholder participation; monitor institutional effectiveness.	Biodiversity; Governance
Role of socio-technical innovations in transforming monitoring and enforcement	Benami et al. (2020); Allena (2019); Luna et al. (2024); Loiselle et al. (2024)	AI/ML enables predictive compliance monitoring; blockchain enhances supply-chain traceability; citizen science fills monitoring gaps and supplements official data. Innovations shift compliance from reactive to continuous and data-rich systems.	Use hybrid systems combining human oversight + AI; ensure data verifiability (e.g., blockchain); integrate citizen-generated data within regulatory workflows.	Pollution; Illegal Logging; Water Governance

Public participation and its influence on authorities, industries, and enforcement bodies	Collins et al. (2023); Cook et al. (2016); Kingston et al. (2021); Loiselle et al. (2024); Facchinelli et al. (2023)	Participation increases monitoring coverage, supports enforcement, and enhances legitimacy. Community-generated data influences regulatory decisions and legal processes. Democratisation strengthens compliance outcomes.	Institutionalise participatory monitoring; ensure mechanisms for public feedback; validate citizen-generated evidence for use in compliance processes.	Water; Biodiversity; Pollution; Climate Justice
Best practices and indicators for future impact assessment	Vandenbergh (2003); Earnhart & Friesen (2024); Benami et al. (2020); Loiselle et al. (2024); Kingston (2021)	Effective compliance systems rely on behavioural drivers, digital monitoring accuracy, governance quality, and stakeholder collaboration. Performance indicators can measure monitoring density, enforcement responsiveness, and participatory engagement.	Develop KPIs for transparency, institutional responsiveness, monitoring quality, and multi-stakeholder involvement.	Multidomain
Role of pollution, biodiversity, and illegal logging in shaping innovation	Bouriaud (2005; 2014); Benami et al. (2020); Loiselle et al. (2024); Kingston (2021); Alblas (2018)	These thematic areas expose unique compliance challenges that stimulate innovation—pollution requires high-frequency monitoring; biodiversity governance demands transparency; illegal logging requires secure traceability and anti-corruption controls.	Tailor compliance tools to sector-specific risks; adopt digital monitoring where enforcement capacity is low; integrate ecological indicators with governance assessments.	Pollution; Biodiversity; Forests

Table 6 - Summary of Grey Literature Review for Environmental Compliance Findings

Research Question	EU-Level Trajectory / Key Developments	National Illustrations (Examples from Dataset)
Evolution of environmental compliance internationally and in the EU	• Shift from formal transposition and infringement-driven enforcement to performance-based, preventive, and systemic compliance. • Integration of compliance into broader frameworks (EIR, Zero Pollution Strategy, Green Deal). • Emphasis on risk-based inspections, cross-agency coordination, continuous monitoring, and adaptive governance.	Greece: Transition from long-standing infrastructure deficits to integrated climate and permitting reforms (Law 4936/2022). Italy: Waste and air-quality infringements evolve into rights-based governance after ECtHR-linked reforms. Romania: Movement beyond acquis transposition toward substantive enforcement against illegal logging. Netherlands: Integrated Environment and Planning Act embeds compliance in spatial planning. Belgium: Increasing focus on transparency and environmental health (PFAS). Spain: Consolidation of marine and waste compliance through updated national frameworks. UK: Hybrid risk-based enforcement remains strong even post-EU.

Disruptive EU regulatory mechanisms shaping compliance systems and market behaviour	• Emergence of value-chain and corporate due-diligence obligations (CSDDD, Deforestation Regulation). • Expansion of restoration, circular economy, and zero-pollution requirements. • Regulatory shift from “permit-based control” to lifecycle accountability and supply-chain traceability. • Greater interaction with finance, trade, human rights, and procurement.	Greece: Licensing simplification and climate governance integrate compliance into economic planning. Italy: Environmental Code updates respond to waste infringements and human rights jurisprudence. Romania: New Forestry Code (2024) operationalises digital traceability and anti-corruption compliance. Belgium: PFAS crisis triggers regulatory tightening, health-oriented compliance. Spain: Marine and waste reforms cascade EU directives into regional and municipal compliance. Netherlands: Strong adaptation capacity to demanding horizontal EU instruments.
Role of socio-technical innovations in transforming monitoring and enforcement	• New compliance paradigm relies on AI/ML analytics, remote sensing, digital twins, and blockchain systems. • Integration of citizen sensors, crowdsourced data, and distributed networks of monitoring technologies. • Transition from episodic inspections to continuous, high-resolution environmental intelligence.	Belgium: CurieuzenAir demonstrates large-scale citizen air-quality mapping integrated into policy debate. Italy: ARPA mobile laboratories generate real-time data in industrial areas (e.g., Malagrotta). Spain: Marine litter monitoring modernised under MSFD requirements. Romania: Digital traceability systems designed for timber circulation. Greece: Urban air pollution monitored via mixed official–citizen systems. Netherlands: Advanced environmental information portals and risk-based inspection algorithms. UK: Watershed citizen-monitoring initiatives support official agencies.

Public participation and its influence on authorities, industries, and enforcement bodies	• Participation becomes central via Aarhus rights, citizen science guidance, access-to-justice tools. • Civil society emerges as a monitoring actor, evidentiary contributor, and catalyst for enforcement. • Media investigations and community mobilisation reshape compliance incentives.	Italy: Terra dei Fuochi activism and ECtHR findings drive institutional reform. Romania: Anti-illegal logging protests and NGO investigations compel enforcement responses. Belgium: Citizen-generated pollution datasets shape municipal action. Greece: NGOs engage legal pathways to challenge permitting and enforcement failures. Spain: Strong civil-society role in marine and biodiversity compliance. Netherlands: Long-established participatory channels integrated into planning processes. UK: Catchment partnerships illustrate co-governance models.
Best practices and indicators for future impact assessment	• EIR and EU compliance assurance frameworks identify models: risk-based inspections, information portals, task-force enforcement, structured citizen science. • Indicators increasingly link administrative performance, digital capacity, participation, and environmental outcomes.	Netherlands: Integrated planning system offers benchmark for coordinated compliance. Belgium: Data transparency and citizen-science processing pipelines serve as replicable models. Spain: Structured marine and waste monitoring systems provide KPI-ready indicators. Italy: Jurisprudence-driven reforms illustrate compliance–rights linkages. Romania/Greece: Rapid institutional adjustments provide lessons for capacity-building indicators.

Role of pollution, biodiversity, and illegal logging in shaping innovation	• Thematic areas act as stress tests and accelerators of compliance reform. • Pollution crises reveal monitoring and enforcement deficits, prompting technological upgrades. • Biodiversity enforcement requires cross-sector coordination and spatial data innovations. • Illegal logging drives adoption of traceability, anti-corruption, and remote-sensing tools.	Pollution: PFAS in Belgium, industrial emissions in Greece, and waste crises in Italy show how crises reshape policy and monitoring. Biodiversity: Natura 2000 challenges in the Netherlands and Germany; marine/maritime biodiversity governance in Spain. Illegal logging: Romania provides the EU's most prominent case, linking corruption, crime and digital enforcement tools. Across all countries, thematic pressures catalyse institutional learning and adoption of new technologies.
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The review highlights that environmental compliance assurance is best understood as a dynamic governance process rather than a static legal requirement. It **spans across promotion, monitoring, and assurance, with evaluation mechanisms** ensuring that progress is both measurable and transparent. A central lesson is that citizen-based innovation cuts across all stages, acting as a catalyst for strengthening legitimacy, expanding monitoring capacity, and creating trust between institutions and communities. The review also highlighted the important role of accountability and public access to environmental data and information. CS practices invite research to address who are the gatekeepers of such data and information, for example environmental compliance authorities, and how access to these resources is democratized in line with the prescriptions of the Aarhus Convention (United Nations Economic Commission for Europe, 1998).

In terms of promotion, the review shows the importance of awareness, capacity building, and the creation of shared responsibility. Compliance cannot rely solely on legal obligations; it requires engaging citizens, stakeholders, and institutions in co-creating solutions that encourage voluntary adherence to environmental rules. For monitoring, lessons highlight the growing role of socio-technical innovations. CS, Earth observation, and digital dashboards complement inspections, bringing both scale and local precision. Earth observation adds unique value by providing objective, high-frequency data across vast and often inaccessible areas, offering historical insights that reveal trends over time, and delivering spatially precise information. Citizen-generated data is particularly valuable for making compliance evidence more legitimate and actionable. Assurance and enforcement emerged as areas where reliable data and proportional responses are critical. Compliance assurance is not limited to punitive measures; it must also recognize voluntary “beyond compliance” practices while ensuring that violations are detected and addressed fairly. Citizen-based reporting tools and participatory monitoring protocols demonstrate how innovation can directly support enforcement.

Finally, evaluation closes the compliance cycle by providing feedback and accountability. Impact Indicators can demonstrate whether compliance actions deliver tangible results such as reduced pollution, biodiversity recovery, or faster detection of illegal logging. Evaluation ensures that compliance systems remain adaptive and capable of continuous improvement. Taken together, the lessons confirm that environmental compliance assurance requires a holistic, participatory, and adaptive framework. **Promotion, monitoring, assurance, and evaluation must be linked in a cycle where citizen-based innovation is fully integrated, ensuring that compliance keeps pace with environmental, technological, and societal change.**

In this context, a mature environmental compliance system cannot be conceptualised solely through the prism of court-admissible enforcement but instead must be understood as a sequence of interdependent tiers that collectively sustain regulatory effectiveness. At the foundational tier, regulatory clarity and preventive governance shape the conditions under which duty-holders understand obligations and manage their environmental risks; this tier includes planning instruments, licensing systems, information portals, compliance guidance, and early-warning monitoring architectures. A second tier involves continuous administrative

oversight through inspections, digital monitoring, environmental reporting, citizen science contributions, and risk-based evaluation. These actions rarely aim directly at judicial proceedings but form the evidentiary and epistemic scaffolding upon which credible enforcement rests. A third tier comprises corrective and deterrent mechanisms – administrative sanctions, orders, and negotiated measures – which operate to restore compliance without necessarily escalating to criminal or judicial processes. Only at the final tier does formal enforcement proceed toward court-level adjudication, with the objective to clarify legal obligations, correct systemic failures, and signal institutional resolve.

This tiered conception is essential across thematic domains. In pollution governance, for example, real-time monitoring and community reporting often detect emerging risks long before any litigation is contemplated; administrative measures, not courts, resolve most breaches. In biodiversity protection, regulatory planning tools (e.g., Natura 2000 management plans, Strategic Environmental Assessments, and Environmental Impact Assessments) constitute preventive tiers that shape compliance far upstream from formal sanctioning. In illegal logging, digital traceability systems and supply-chain due diligence requirements serve as primary compliance tiers that aim to eliminate risk before enforcement is mobilised. Across these domains, tiered compliance frameworks also enable the integration of socio-technical innovation – AI/ML anomaly detection, satellite surveillance, blockchain traceability, and participatory monitoring – which enhances regulatory capacity without displacing the limited, high-threshold domain of court-admissible enforcement.

Understanding compliance through these graduated tiers aligns with contemporary EU policy, which emphasises systemic performance rather than isolated punitive actions. It also reflects empirical realities documented across Member States in the grey literature and national reports: Greece’s climate law reforms rely heavily on administrative preventive tiers. Key outcomes of this initial framework based on literature are presented in Table 6.

Table 7 - Initial ECCI Conceptual Framework Principles based on Environmental Compliance Review Findings

Compliance Phase	Embedded Tiers (How the Phase Operates)	Key Functions	Citizen-Based Innovation (Cross-Cutting Contribution)	Examples Across Thematic Areas & Countries
1. PROMOTION	Tier 1 – Preventive Governance (regulatory clarity, guidance, early warning)	• Establish norms and expectations • Build capacity and awareness • Reduce ambiguity around obligations • Promote voluntary compliance	• Co-created awareness materials • Public access to environmental data (Aarhus) • Community mobilisation & journalism highlighting risks	Pollution: Awareness on PFAS in Belgium Biodiversity: Natura 2000 participatory planning (Greece, Spain) Forestry/Illegal Logging: Transparency campaigns in Romania
2. MONITORING	Tier 2 – Continuous Administrative Oversight (inspections, EO, digital tools, reporting)	• Detect irregularities early • Generate evidence • Increase monitoring density • Support risk-based oversight	• Citizen science sampling (Loiselle et al., 2024) • EO interpretations with communities • Environmental hotlines & apps • Localised intelligence gathering	Pollution: Real-time monitoring in Italy, Greece Biodiversity: Citizen species reports in the Netherlands Illegal Logging: Romania's traceability system + CS reporting
3. ASSURANCE & NON-JUDICIAL ENFORCEMENT	Tier 3 – Corrective & Deterrent Measures (administrative sanctions, remediation orders, negotiated compliance)	• Restore compliance proportionately • Correct behaviours without escalation • Provide incentives for “beyond compliance” actions • Ensure fairness and transparency	• Citizen alerts prompting corrective actions • Public visibility of non-compliance • Co-designed compliance protocols	Pollution: Administrative responses to PFAS (Belgium) Biodiversity: Adaptive management decisions in Spain/Italy Illegal Logging: Administrative penalties linked to digital logs (Romania)
4. EVALUATION	Tier 4 – Judicial Enforcement (criminal/civil adjudication; systemic rulings) <i>plus</i> Cross-Tier Feedback Loops	• Assess whether compliance actions work • Produce impact indicators • Ensure accountability and transparency • Adapt governance systems	• Citizens contributing outcome data • Strategic litigation • Public scrutiny of published indicators • Community-based evaluation panels	Pollution: Litigation over industrial waste in Italy Biodiversity: EU Habitats Directive infringement cases Illegal Logging: Court-supported anti-corruption efforts (Romania)

The classical EU model of environmental compliance assurance – structured around compliance promotion, monitoring, and assurance/enforcement—provides the foundation upon which the more analytical, four-phase and four-tier framework developed in this report expands. The ENFORCE analytical model integrates and deepens the EU’s three stages by disaggregating assurance/enforcement into two distinct phases: a corrective tier, focused on proportionate administrative responses, and a judicial-adjacent tier, addressing evidentiary standards, admissibility requirements, and the escalation to punitive processes. Similarly, the traditional promotion stage is broadened into a preventive governance tier that includes behavioural interventions, participatory infrastructures, early-warning architectures and pre-crime risk planning. Monitoring is reinterpreted not only as observation but as a socio-technical evidence-generation system composed of official inspections, satellite analytics, sensor networks and citizen science.

Finally, the ENFORCE framework adds evaluation as a fourth phase, creating explicit feedback loops that allow regulatory systems to learn, adapt and improve - an element implicit but underdeveloped in the EU’s three-stage model. Through this integration, the analytical framework retains the structural logic of EU compliance assurance while making visible the mechanisms, capacities and data pathways that determine whether promotional, monitoring, or enforcement actions actually translate into improved compliance outcomes. It also clarifies where innovations intervene in the cycle, thereby operationalising the theory of change underpinning the project.

3.2.2 Insights from the review of procedural law and judicial cases (T2.2) ²³

Following initial analysis on regulatory framework provided above, the analysis below concentrates on the procedural and evidentiary rules applicable in criminal courts, rather than on substantive environmental legislation. Understanding evidentiary admissibility is essential to assessing how environmental offences are investigated and proved.

The administration of criminal justice in Europe is defined by a diverse set of procedural rules, as the European Union lacks a unified code of criminal evidence. Despite this legal autonomy, many member states share foundational principles rooted in constitutional rights and international jurisprudence. The present study analyses the admissibility of evidence, the principles for its judicial evaluation, and the rules governing its exclusion across jurisdictions of the case studies and specifically Belgium, the Netherlands, Spain, Romania, Italy, Greece and the UK. While these

²³ The legal context presented herein is based on preliminary and initial research conducted up to December 2025. This research has been undertaken with the objective of prioritizing key areas of regulatory and legal compliance within the ENFORCE countries. The scope of this analysis is not exhaustive, nor should it be interpreted as exclusive to those jurisdictions or compliance domains explicitly referenced. Legal and regulatory frameworks are subject to ongoing change, interpretation, and jurisdiction-specific application. Accordingly, the information provided should be regarded as dynamic and subject to continuous validation, refinement, and expansion throughout the lifecycle of the project. This material is intended for informational and analytical purposes only and does not constitute legal advice. It should be read in conjunction with updated project documentation (e.g. reports to citizens and prosecutors to be developed) and, where appropriate, supplemented by consultation with qualified legal professionals.

nations all seek to balance the discovery of truth with the protection of individual rights, they do so through distinct, and at times, contrasting legal frameworks.

Belgium

Belgian criminal procedure is marked by a broad admissibility of evidence, tempered by the principle that judges and jurors evaluate all evidence according to their inner conviction, without a formal hierarchy of probative value. This freedom of evaluation is firmly established in Articles 195, 211, 330, and 342 of the Code of Criminal Procedure (CCP) and has been repeatedly confirmed by the Court of Cassation. At the same time, the admissibility of evidence is not unlimited. Since the Antigoon ruling of 2003, now codified in Article 32 of the Preliminary Title, unlawfully obtained evidence may be admitted unless it is formally null, unreliable, or incompatible with the right to a fair trial. These principles together ensure both flexibility and fairness in the treatment of evidence in Belgian criminal trials.

1. Kinds of Evidence Admissible

Belgium adheres to the principle of freedom of evidence. This means that, in principle, any form of evidence can be presented in criminal proceedings, provided it is relevant to the case. The Belgian Code of Criminal Procedure does not contain a closed list of admissible categories, but different provisions regulate the way particular kinds of evidence are introduced. Witness testimony is governed by Articles 190 to 198 CCP in relation to correctional tribunals and Articles 318 to 336 CCP for proceedings before the courts of assizes. Expert investigations, such as medical or technical reports, are provided for in Articles 43 to 62 CCP. Documentary evidence, including police reports and official documents, is referred to in Articles 37 to 62 CCP and Articles 190 to 191 CCP. Material evidence, such as objects seized during an investigation, is dealt with in Articles 42 and 61ter CCP, while the interrogation of suspects and the use of their statements or confessions is regulated by Article 47bis and Articles 216 to 217 CCP. Case law confirms the equal standing of these forms of evidence under the principle of freedom of evidence.

2. Principles of Judicial Evaluation

The evaluation of evidence in Belgian criminal trials is founded on the principle of inner conviction. This means that judges and jurors are free to form their opinion based on their conscience, without being bound by any formal hierarchy of evidence.

This principle is explicitly enshrined in several provisions of the Code of Criminal Procedure. Article 195 CCP provides that courts in police and correctional matters shall decide according to their free conviction, unless the law has given specific probative force to a particular kind of evidence. Article 211 CPP further requires judgments to state the reasons which convinced the judges of guilt or innocence, while making clear that they are not obliged to explain the relative weight of each individual piece of evidence.

In jury trials, the same principle applies. Article 330 CCP requires the presiding judge of the court of assizes to remind jurors that the law does not ask them to justify how they were convinced, but only to decide according to their conscience, with impartiality and firmness. Article 342 CCP

repeats this principle when jurors deliberate, confirming that verdicts are rendered on the basis of inner conviction. The Court of Cassation has consistently reaffirmed this doctrine. In its jurisprudence, the Court has held that all evidence — whether witness testimony, confessions, documents, or material objects — must be assessed freely by the trial judge or jury. The only exceptions are those expressly provided for by law, such as the evidentiary force attached to authentic public documents.

3. The Regime for the Exclusion of Evidence

The exclusion of unlawfully obtained evidence in Belgian law is regulated by Article 32 of the Preliminary Title of the Code of Criminal Procedure. This provision codifies the principle developed by the Court of Cassation in its seminal judgment of 14 October 2003 (the Antigoon case). Prior to that decision, Belgian law tended toward the automatic exclusion of illegally obtained evidence. In Antigoon, however, the Court broke with this tradition and ruled that such evidence could still be admitted, except in three situations: first, where the law explicitly attaches the sanction of nullity to the procedural irregularity; second, where the manner in which the evidence was obtained undermines its reliability; and third, where its admission would violate the right to a fair trial.

The result is a pragmatic exclusionary regime: evidence is not automatically excluded simply because of an irregularity in how it was obtained. Instead, the trial judge must apply the Article 32 criteria to determine whether the evidence is still admissible. This system emphasizes judicial discretion, balancing the need for procedural legality with the overarching right to a fair trial.

The Netherlands

The Dutch criminal justice system regulates evidence through a highly codified and distinctive framework. Unlike jurisdictions that allow any relevant material to be admitted subject to reliability tests, the Netherlands maintains a “closed system of proof,” where only specific categories of evidence qualify as lawful. At the same time, Dutch law entrusts judges with broad discretion in how they evaluate that evidence, subject to certain statutory safeguards.

1. Kinds of Evidence Admissible

The cornerstone of the Dutch evidentiary framework is Article 339 of the Dutch Code of Criminal Procedure (CCP) (*Wetboek van Strafvordering*). This article enumerates the five lawful means of proof (*wettige bewijsmiddelen*): the judge’s own observations, statements of the accused, statements of witnesses, statements of experts, and written documents. The system is closed—no other form of material can serve as direct legal proof. Facts of general knowledge require no proof (Art. 339(2) CCP). This restriction has practical implications. Newer forms of evidence, such as digital data or audiovisual material, must be “routed” through the lawful categories. For example, electronic records may be admitted as written documents via police reports (*proces-verbaal*), while video footage may be used as a written document or as the judge’s personal observation. Dutch case law has consistently upheld the closed nature of the system. The Supreme Court (*Hoge Raad*) has stressed that evidence not fitting the statutory forms cannot be used as proof of guilt (HR 1 February 1994, NJ 1994, 427). Another important safeguard is the so-called “*unus testis*,

nullus testis” rule codified in Article 342(2) CCP, which prohibits conviction based solely on the testimony of a single witness. This has been reaffirmed in HR 21 April 1998, NJ 1998, 614.

2. Principles of Judicial Evaluation

While the law prescribes what counts as lawful evidence, the weight and persuasiveness of that evidence is left largely to the trial judge. Article 338 CCP sets the central standard: the judge may only conclude that the accused committed the charged offense if she has obtained personal conviction (*rechterlijke overtuiging*) from the lawful evidence presented during the trial. This principle means that the judge’s subjective belief in guilt must align with the objective availability of lawful proof. The Dutch system also embraces the principle of immediacy (*onmiddellijkheidsbeginsel*), which requires that the judgment be based on evidence presented and tested at trial. Although written reports from the investigation can serve as lawful evidence, the defense must have an opportunity to challenge them through confrontation rights, in line with European Court of Human Rights jurisprudence (*Al-Khawaja and Tahery v. UK*). Additionally, Article 359 CCP imposes a reason-giving obligation. The judgment must set out the evidence relied upon and explain why it was considered convincing. This guarantees transparency and enables appellate review by higher courts. At the same time, Dutch judges enjoy freedom of proof evaluation (*vrije bewijswaardering*). Within the confines of the lawful categories, they decide the weight to attach to each item. A single credible witness statement (not subject to the “one witness” rule) may suffice for conviction, while extensive forensic evidence might be discounted if deemed unreliable. In the celebrated Porsche case (HR 14 April 1998, NJ 1998, 493), the Supreme Court clarified that conviction requires not only lawful evidence but also genuine judicial conviction, underscoring the dual subjective and objective dimensions of proof.

3. The Regime for the Exclusion of Evidence

Unlike some systems that automatically exclude unlawfully obtained material, Dutch law adopts a restrained and pragmatic approach. The governing rule is Article 359a CCP, introduced in 1996. This provision applies when procedural rules are violated during the investigation and the law does not prescribe a consequence. The court may then choose among three remedies: (a) reduction of sentence in proportion to the seriousness of the violation; (b) exclusion of the evidence obtained through the violation; or (c) declaring the prosecution inadmissible if the violation makes a fair trial impossible. The choice of remedy is guided by three considerations: the purpose of the violated rule, the seriousness of the breach, and the prejudice caused to the defendant. Case law has clarified the contours of this regime. In the landmark Zwolsman judgment (HR 19 December 1995, NJ 1996, 249), the Supreme Court held that exclusion of evidence is mandatory when investigative authorities seriously infringe fundamental rights in a manner that undermines the fairness of the trial. However, prosecution inadmissibility is reserved for extreme cases involving structural and deliberate breaches of due process. Later decisions, such as HR 19 February 2013, NJ 2013, 308, confirmed that minor or technical errors usually result in sentence reduction rather than exclusion. Thus, Dutch courts tend to admit unlawfully obtained evidence unless its use would compromise fairness in a fundamental way.

Spain

The Spanish criminal justice system is governed by the principles of *prueba libre* (free proof) and judicial evaluation according to reason and law. Although Spanish law is receptive to diverse forms of evidence, admissibility is always conditioned by strict constitutional and statutory safeguards. The Ley de Enjuiciamiento Criminal (LECrim), the Spanish Constitution (Constitución Española, CE), and the Ley Orgánica del Poder Judicial (LOPJ) together form the normative framework, complemented by extensive jurisprudence from the Tribunal Supremo (TS) and the Tribunal Constitucional (TC). Three areas are particularly decisive: the kinds of evidence admissible, the principles guiding judicial evaluation, and the regime of exclusion for illegally obtained material.

1. Kinds of Evidence Admissible

The starting point in Spanish criminal law is the broad admissibility of evidence. Article 741 LECrim requires that judgments be based on "all the evidence that has been lawfully produced during trial." The statute thus embraces testimonial, documentary, expert, material, and increasingly, digital evidence. Testimonial evidence is regulated in Articles 410–450 LECrim, documentary evidence is addressed in Articles 726–730 LECrim, expert evidence (*prueba pericial*), is regulated in Articles 456–485 LECrim, material or physical evidence, is governed by Articles 326–334 LECrim. Finally, digital and technological evidence has become central since the reform of 2015 (Organic Law 13/2015). New provisions in Book II, Title VIII, Chapter V–VII of LECrim regulate interception of communications, seizure of digital devices, remote access to electronic data, and use of GPS tracking.

2. Principles of Judicial Evaluation

The Spanish model of judicial assessment rests on three interrelated principles: freedom of evaluation, relevance and necessity, and adversarial contradiction. Freedom of evaluation (*libre valoración de la prueba*) is enshrined in Article 741 LECrim. Judges are not bound by rigid rules of evidence but must form their conviction through rational assessment according to the criteria of *sana crítica*. This principle has been consistently reaffirmed in case law, including STS 142/2002, which underscored judicial independence in attributing credibility. Relevance and necessity govern admissibility at the threshold. Judges may exclude irrelevant or dilatory evidence under Article 659 LECrim. In STS 106/2008, the Supreme Court highlighted the duty of courts to balance probative value against efficiency, ensuring that only evidence necessary for establishing facts is admitted. Contradiction and equality of arms are protected under Article 24.2 CE, which guarantees the rights of defense and adversarial participation. The Constitutional Court has long recognized that adversarial testing is essential for reliability. In STC 50/1987, it ruled that the absence of contradiction renders evidence constitutionally defective. Finally, the principle of the presumption of innocence (Art. 24.2 CE) serves as the ultimate evaluative standard. Only evidence that is both lawfully obtained and sufficiently probative can rebut this presumption. In STC 31/1981, the Constitutional Court clarified that convictions may not rest on police reports alone but must be supported by evidence tested in court. Similarly, in STS 12/1992, the Supreme Court reiterated that only trial evidence—not pre-trial materials—may form the basis of conviction.

3. The Regime for the Exclusion of Evidence

Perhaps the most developed area of Spanish evidence law is the doctrine of exclusion of illegally obtained evidence. It reflects the constitutional commitment to fundamental rights and the rule of law. The constitutional basis is found in Articles 24 and 18 CE. Article 24 guarantees a fair trial and effective judicial protection, while Article 18 protects privacy, domicile, and the secrecy of communications. Evidence obtained in violation of these rights is inadmissible. This principle is codified in Article 11.1 LOPJ, which explicitly states: "Evidence obtained in violation of fundamental rights shall not have effect." The Spanish Constitutional Court has extended the exclusionary rule to derivative evidence (*prueba derivada*), embracing the doctrine of the "fruits of the poisonous tree." In STC 85/1994 and STC 49/1996, it ruled that evidence obtained through unconstitutional wiretaps or searches, as well as all evidence causally derived from them, must be suppressed. Later decisions, notably STC 81/1998 and STC 94/1999, refined this approach by introducing the test of "disconnection of unlawfulness" (*desconexión de antijuridicidad*), under which derivative evidence may be admitted if there is an independent lawful source or a sufficient break in the causal chain. This framework, echoed by the Supreme Court, underlines that unlawfulness contaminates evidence unless a clear and objective disconnection restores its legitimacy.

Romania

The administration of justice in criminal matters depends fundamentally on how evidence is defined, collected, assessed, and, where necessary, excluded. In Romania, the regime governing the admissibility of evidence is codified in Law no. 135/2010 on the Criminal Procedure Code (CPC). This framework not only specifies the types of evidence that may be relied upon by the courts but also establishes the principles guiding their evaluation and the mechanisms ensuring the exclusion of unlawfully obtained material. Additionally, the jurisprudence of the Court of Justice of the European Union (CJEU) plays a binding role in criminal proceedings, particularly when EU law provisions are at stake, ensuring uniform interpretation and application across Member States. According to Article 147 of the Romania Constitution, the jurisprudence of the Constitutional Court of Romania (CCR) is mandatory and must be applied once published. Furthermore, under Article 20 of the same Constitution, Romania, as a party to international treaties on human rights, is required to give effect to those provisions whenever they offer more favorable protection. Consequently, the jurisprudence of the European Court of Human Rights (ECHR) is regarded as a secondary source of law, playing a significant role in the national legal framework. As emphasized in Article 1 of the Criminal Procedure Code (CPC), the norms of criminal procedure are designed not only to regulate the conduct of criminal proceedings but also to guarantee the rights of the parties and participants in accordance with the Constitution, EU founding treaties, other EU regulations in criminal procedure, and international human rights treaties to which Romania is a party. This highlights the integrated role of domestic law, EU law, and international human rights jurisprudence in ensuring fair and effective criminal justice. In conclusion all three courts CCR, CJEU and ECHR contribute to strengthening the uniformity and predictability of how legislation is enacted, interpreted and applied by the domestic courts in

Romania. In addition to external and constitutional sources, according to Article 471 of the Criminal Procedure Code, the decisions of the High Court of Cassation and Justice (HCCJ) on the settlement of legal questions also play a crucial role in ensuring the uniformity of the application of criminal legislation by Romanian courts. These decisions establish binding interpretations of the law, thereby contributing to the coherence of the national judicial system.

1. Kinds of Evidence Admissible

The legal basis for the admissibility of evidence is Article 97 CPC, which states that evidence consists of any factual element capable of establishing the existence or non-existence of the subjective and objective elements of the criminal offence. After the start of a process *in personam* the criminal investigation bodies have to gather evidence both in favor and against the accused person, as stated in Article 306 of CPC, in order to clarify any circumstances relevant for a fair trial. This broad definition reflects one of the Criminal procedural law core principles, stipulated in Article 5 of the CPC, truth finding: evidence can be defined as any means that can contribute to the discovery of truth in criminal proceedings, so long as it is not expressly prohibited by the law. The same provision of Article 97 CPC lists the types of evidence that can be admitted, namely: the statements of the suspect or accused; statements of the injured party; statements of the civil party or the party bearing civil liability; witness testimony; written documents, expert or statement of findings reports, official records, photographs and other material means of proof; as well as any other means of evidence permitted under the law. The CPC therefore embraces both traditional testimonial forms of proof and expert-based evidence. Supplementary provisions (Articles 104–105 CPC) regulate the categories of interested parties who may be invited to one or more hearings—suspects, accused, injured parties, civil parties, civil liable parties, witnesses and experts. Special regulations are applicable for non-Romanian speakers and disabled persons, who are entitled to interpretation services during hearings. Further articles (172–183 CPC) provide detailed rules for expertise and findings reports, which are particularly important in complex cases. Certain admissible means of evidence have been shaped by case law. An example is CCR Decision no. 51/2016 which held that technical surveillance can be carried out by the prosecutor or by the criminal investigation body or specialized workers within the police, if authorised by the prosecutor. The said CCR Decision ruled that the legal provision allowing “other specialized state bodies” to carry out technical surveillance is unconstitutional. In the same time, CCR Decision no. 55/2020 ruled that the legal provisions from Emergency Ordinance No. 6/2016 on certain measures for the enforcement of technical surveillance warrants ordered in criminal proceedings, allowing Romanian Intelligence Services (SRI) to perform technical surveillance are unconstitutional, if the evidence obtained is not authorised through warrant previously, after the start of the criminal investigation *in rem*.

2. Principles of Judicial Evaluation

The Code provides that evidence has no predetermined legal value: under Article 103(1) CPC, each piece of evidence is subject to the free assessment of the judicial authorities. Judges are thus required to form their conviction only after evaluating all of the evidence administered in the case. This principle of “free assessment” balances judicial discretion with the duty to provide thorough

reasoning in judicial decisions. Article 103(2) CPC states that a conviction may be pronounced only when the court is convinced that the accusation has been proven beyond any reasonable doubt, which is based on another important principle, that of the innocence presumption established through Article 4 of the CPC. This threshold mirrors the jurisprudence of the ECHR, notably in *Barberà, Messegue and Jabardo v. Spain* (1988), from which it follows that proof must attain such a level that no reasonable doubt remains as to guilt. The Romanian courts have embraced this standard, ensuring that the presumption of innocence—enshrined in Article 99(2) CPC—is not undermined by insufficient or speculative evidence. Furthermore, Article 103(3) CPC prohibits courts from basing a conviction, in a decisive manner, solely on testimony from investigators, collaborators or protected witnesses. Complementing these provisions, Article 100 CPC requires the judicial bodies to gather and administer evidence both for and against the accused, while Article 101 CPC codifies the principle of fairness in evidence gathering. Violence, threats, promises, or coercive interrogation methods are strictly forbidden, and evidence must be collected in a way that respects the individual’s ability to give voluntary and conscious statements.

3. The Regime for the Exclusion of Evidence

The exclusionary rule is expressly enshrined in Article 102 CPC. It provides that evidence obtained through torture, as well as evidence derived from it, or evidence obtained in breach of the law may not be used in criminal proceedings. Importantly, the provision of Article 118 (3) CPC establishes that a statement given as a witness by a person who has, in the same case, has had or becomes a suspect or accused person, cannot be used against them, in this way excluding self-incrimination. Exclusion operates both as a procedural safeguard and a deterrent against investigative abuses. Under Article 100(4) CPC, judicial authorities may also refuse to admit evidence if it is irrelevant, unnecessary, already established, impossible to obtain, requested by an unauthorised person, or contrary to the law. This exclusionary framework has been vigorously applied in Romanian case law. The Constitutional Court of Romania in its Decision no. 383/2015 affirms that any evidence obtained through unlawful or procedurally void methods must be excluded, consistent with the regime of procedural nullity. While the decision does not explicitly invoke a “fruits of the poisonous tree” rationale, it underlines that inadmissible evidence cannot be used in criminal proceedings—a principle that parallels protection against “derivative contamination”. These rules underline that finding truth in criminal justice cannot be pursued at any cost: evidence must be both probative and lawfully obtained, otherwise it undermines the legitimacy of the process.

Italy

The Italian criminal process is governed primarily by the Italian Code of Criminal Procedure, *Codice di Procedura Penale* (CPP), as well as constitutional provisions and extensive jurisprudence of the Court of Cassation (*Corte di Cassazione*) and the Constitutional Court (*Corte Costituzionale*). Italian law provides a structured yet flexible framework for the collection, admission, and evaluation of evidence, reflecting a balance between the need for truth-finding and the protection of individual rights. This essay outlines the kinds of admissible evidence, the principles for judicial evaluation, and the regime of exclusion.

1. Kinds of Admissible Evidence

Italy has a codified framework (closed system) that enumerates lawful means of evidence in criminal trials. The starting point is found in Articles 187–193 CPP, which set the general rules. Article 187 defines the object of proof: facts relating to the charge, punishability, the determination of penalties or security measures, procedural conditions, and, when a civil party participates, facts concerning civil liability. Article 188 protects the moral freedom of the person by prohibiting methods or techniques that influence self-determination or memory, while Article 189 allows the admission of “atypical” evidence, provided it is reliable and does not infringe fundamental freedoms. Article 190 codifies the “right to evidence”: parties may request admission of proof, and the judge must exclude only what is prohibited, manifestly irrelevant, or superfluous. Article 191 introduces the principle of “*inutilizzabilità*” (inadmissibility), excluding evidence acquired in violation of prohibitions, while Article 192 sets the criteria for evaluation, and Article 193 specifies that civil law limits on proof do not generally apply, save for matters of personal status and citizenship. Within this framework, the Code distinguishes between “means of evidence” (*mezzi di prova*), regulated in Articles 194–243 CPP, and “means of searching for evidence” (*mezzi di ricerca della prova*), set out in Articles 244–271 CPP. The former includes witness testimony (194–207), the examination of the accused (208–210), confrontations (211–213), identifications (214–219), judicial experiments (220–224), expert opinions (225–233), and documents (234–243). The latter encompasses inspections (244–246), searches (247–252), seizures (253–263), and interceptions (266–271). This codified list reflects a system that is at once closed—enumerating typical means of proof—and open, thanks to Article 189, which permits new or unregulated forms of evidence (for example, novel forensic techniques) if they respect constitutional and statutory guarantees.

2. Principles of Judicial Evaluation

The central statutory provision is Article 192 CPP, which obliges the judge to motivate the assessment of evidence, prohibits reliance on mere clues unless they are “grave, precise, and consistent”, and requires external corroboration for statements made by co-defendants or individuals accused in connected proceedings. This provision has long served as a cornerstone of Italian evidentiary jurisprudence. Evaluation is also framed by Article 533 CPP, which establishes the standard of proof: a conviction may be pronounced only if the defendant’s guilt is established “beyond a reasonable doubt.” This principle reflects the constitutional guarantees of Article 111 of the Constitution, which enshrine the adversarial formation of evidence and equality of arms. Case law has deepened these principles. In Cass., Sez. Unite, 11 September 2002, n. 30328 (“Franzese”), the Supreme Court laid down rigorous criteria for evaluating scientific and causal evidence, holding that inferences from expert findings must reach a high threshold of logical probability. In Cass., Sez. Unite, 12 July 2005, n. 33748 (“Mannino”), the Court refined the doctrine of circumstantial evidence, reaffirming the demand for coherence and strict adherence to the “grave, precise, and consistent” triad of Article 192(2). More recently, in Cass. pen., 30 June 2022, n. 25016, the Court applied the reasonable doubt standard to chains of circumstantial proof, stressing that each link must be logically solid for a conviction to stand.

3. The Regime for the Exclusion of Evidence

The principal exclusionary rule is found in Article 191 CPP, which declares that evidence obtained in violation of prohibitions established by law is unusable, and this inadmissibility may be recognized by the court at any stage of the proceedings. Paragraph 2-bis, added in 2017, specifies that statements or information obtained through torture are inadmissible under any circumstances, except in proceedings against the perpetrator of the torture to prove that crime. This provision is reinforced by Article 188 CPP, which renders inadmissible evidence obtained through methods compromising a person's moral freedom. A contested issue has been whether unlawfulness contaminates derivative evidence—the so-called “fruits of the poisonous tree.” Traditionally, the Court of Cassation adhered to the *maxim male captum, bene retentum*, meaning that illegally obtained material (e.g., through a defective search) could nonetheless be retained and used if the item itself was relevant and not directly tainted. A key example is Sez. Unite “Sala”, 27 March 1996, which epitomized this restrictive approach to derivative inadmissibility. However, in recent years the Constitutional Court has shifted the balance towards greater protection. In Judgment no. 219 of 2019, the Court insisted that searches and inspections lacking judicial validation or adequate reasoning could render the evidence unusable, as otherwise constitutional guarantees (Arts. 13–14 Cost. on personal liberty and domicile) would be undermined. In Judgment no. 252 of 2020, it stressed the need for effective judicial control over intrusions into fundamental rights, hinting that derivative exclusion might apply where constitutional violations were at stake. More recent Constitutional Court jurisprudence has recognized that evidence obtained as a consequence of unlawful investigative acts may also be unusable, when necessary to safeguard constitutional rights. This jurisprudence has progressively eroded the traditional Cassation stance and brought Italian law closer to rights-protective exclusionary doctrines. Additional specific exclusionary rules exist. Article 195 CPP places limits on hearsay testimony, especially where the declarant cannot be identified or confronted, aligning with the confrontation guarantee of Article 111 Cost. Interceptions under Articles 266–271 CPP are also subject to strict authorization and procedural safeguards; violations in their collection or storage can trigger inadmissibility under Article 191.

Greece

In Greek criminal procedure, the evidentiary system is structured around a broad principle of admissibility, tempered by constitutional safeguards. While the Code of Criminal Procedure (CCP) - *Κώδικας Ποινικής Δικονομίας* [in Greek], recognizes six principal means of proof, it expressly allows any form of evidence unless prohibited by law. This openness is balanced by the principle of free evaluation, which grants judges discretion to form their inner conviction, and by strict constitutional limits that exclude material obtained through rights violations. Over time, Greek case law and legislative reforms have shaped a nuanced regime that seeks to reconcile judicial freedom in assessing evidence with the protection of fundamental liberties and the integrity of the trial. The discussion of this jurisdiction is accompanied by a case insight box which is considered very illustrative of an environmental violation with potential to be detected through the reliance on citizen science approaches.

1. Kinds of Evidence Admissible

In Greek criminal procedure, the law recognizes six principal evidentiary means—circumstantial evidence, on-site inspection, expert reports, confession, witness testimony, and documents—under Article 178 CCP, but makes clear that any form of evidence is admissible unless prohibited by law. The Code then devotes specific provisions (Arts. 179–253 CCP) to regulate each category in detail, ensuring that while judges enjoy the freedom of evidence evaluation, this discretion is exercised within a framework of legality, fairness, and constitutional safeguards.

2. Principles of Judicial Evaluation

The evaluation of evidence in Greek criminal procedure is shaped by a set of principles that combine judicial freedom with constitutional safeguards. At the core lies the principle of free evaluation of evidence (Art. 177 §1 CCP), which allows judges to form their conviction freely, guided by conscience and impartial reasoning. This freedom is balanced by the duty of reasoned judgment (Art. 93 §3 Const., Art. 139 CCP), requiring courts to explain explicitly which evidence they relied upon. Judicial discretion is limited by the principle of legality of evidence: under Art. 177 §2 CCP and Art. 19 §3 Const., evidence obtained through criminal acts or in violation of rights (privacy, communications, personal data) is inadmissible. The presumption of innocence is firmly entrenched in Art. 178 §2 CCP (as amended by Law 4596/2019), which places the burden of proof entirely on the prosecution and obliges judges and prosecutors to consider both incriminating and exculpatory evidence. Greek trials also follow the principle of immediacy, requiring evidence to be presented and assessed directly in court, and the adversarial principle, rooted in Art. 6 ECHR, ensuring both parties can challenge and comment on the evidence. Finally, the principle of proportionality (Art. 25 §1 Const.) requires balancing privacy rights against higher legal goods, sometimes invoked by courts in exceptional cases.

The Regime for the Exclusion of Evidence Article 19 §3 of the Constitution of Greece states that any evidence gathered through violations of communications secrecy, home inviolability, or data protection is absolutely inadmissible in court. Moreover, article 177 §2 CCP excludes from criminal proceedings evidence that has been obtained through criminal acts, or by means of such acts. In cases of serious financial or corruption crimes, certain restrictions on evidence do not apply if prosecutors are legally entitled to access the information. Such evidence can be used in court if the harm from obtaining it is much less than the harm caused by the crime, the truth could not otherwise be proven and the method of obtaining it does not violate human dignity. This exception could be considered controversial to the constitutional provisions of article 19 §3. It is also interesting that Article 65 N. 4356/2015 was abolished with the introduction of the new CCP with law 4596/2019 and was restated with article 14 of law 4637/2019.

From the combined provisions of Articles 177, 178, and 179 CCP it follows that, in criminal proceedings, every kind of evidentiary means is permitted, whether among those listed in Article 178 or others, even those that are formally void, unless their use is prohibited by law either expressly or because it is contrary to provisions of the applicable procedural system. In such a case, their use infringes the right of defence of the accused and results in absolute nullity of the

proceedings under Article 171 §1(d) of the CPP. (Greek Court of Cassation *Άρειος Πάγος* 1801/2016, 1408 / 2022) The prescribed absolute prohibition on the procedural use of such items of evidence must be reviewed by the criminal court hearing the case, in order to determine whether it is compatible with Articles 2 §1 and 25 §1(d) of the Constitution, which protect the supreme good of human dignity, so that the legally protected interests of life, honour, and liberty of the individual — which enjoy absolute constitutional protection — are not placed at risk. This rule of prohibiting the use of unlawfully obtained evidence, established by that provision and by Article 19 §3 of the Constitution, is relaxed in exceptional cases, not only in favour of but also against the accused. Thus, subject to the principle of proportionality, such “illegal” evidence may be taken into account by the court when it constitutes the only possible element on which the victim can rely to file a complaint and seek judicial protection under Article 20 §1 of the Constitution, or when it is the only evidence offered by the accused to prove his innocence. (Greek Court of Cassation 1367/2020, 277/2014, 1202/2011, 816/2006, 1136/2024).



Picture of the road opened in Natura 2000 site (see case box that follows)

Environmental Case Summary – Unauthorized Road Opening in Natura 2000 Area, Heraklion

1. Case Overview

An environmental violation was brought to the attention of the Environmental Department of Heraklion, Directorate of Environment and Spatial Planning, Region of Crete. The case concerns unauthorized land clearing and the opening of a non-permitted road in the south coastal zone of Heraklion Prefecture. The activities occurred within a Natura 2000 protected area.

2. Location and Protection Status

The affected area falls within the boundaries of the following Natura 2000 sites: GR4310012 – Site of Community Importance (SCI); GR4310004 – Special Protection Area (SPA). These designations signify high ecological value, requiring strict compliance with EU and national environmental legislation.

3. Description of the Violation

An unlicensed road was opened along the coastal zone with the following characteristics: approximate length: **600 meters**; maximum width: 15 meters. The construction was executed without authorization, resulting in significant alterations to the natural environment.

4. Environmental Impacts Identified

4.1 Physical and Landscape Alteration

- Embankments and excavation works visibly changed the natural topography.
- The landscape was disturbed, reducing natural continuity and affecting visual integrity.

4.2 Ecological Damage

- The destruction of sand dune formations, which constitute highly sensitive and protected coastal ecosystems.
- Disturbance of local flora and potential impacts on fauna associated with dune habitats.
- Disruption of ecological processes essential for the stability of the coastal zone.

5. Administrative Findings and Actions Taken

No offender was identified: despite investigation, the responsible party could not be located. Immediate mitigation: the unauthorized road was sealed off from both ends to prevent further use and halt additional degradation. Case transfer: the file was forwarded to the competent authority responsible for environmental restoration actions. Restoration decision: after evaluation, the authority concluded that natural regeneration would be the most appropriate remedy, opting to leave the area undisturbed to allow for spontaneous ecological recovery.

6. Next Steps

Scheduled re-inspection:

A follow-up site visit is planned to assess the progress of natural restoration, evaluate whether ecological functions are recovering, and determine if further interventions are required.

The United Kingdom

The UK evidentiary landscape combines shared principles with jurisdictional diversity. England, Wales and Northern Ireland adopt codified statutory schemes balancing probative value against fairness, while Scotland retains a distinct common-law system grounded in voluntariness, corroboration, and the *Lawrie v Muir* fairness test.

Despite structural differences, the overarching UK framework reflects a unified commitment to relevance, reliability, and fairness as the touchstones of admissibility.

1. Kinds of Evidence Admissible

Across the United Kingdom, admissibility is grounded in the twin principles of relevance and fairness, though the governing frameworks differ.

England and Wales

Admissibility is codified primarily in the Criminal Justice Act 2003 (CJA 2003), the Police and Criminal Evidence Act 1984 (PACE), and the Youth Justice and Criminal Evidence Act 1999 (YJCEA 1999). Key categories include:

- Oral testimony of competent witnesses;
- Hearsay, admissible only through the statutory “gateways” in CJA 2003, ss. 114–136;
- Confessions, governed by PACE, ss. 76–76A, admissible only if voluntary and reliable (*R v Fulling* [1987] QB 426);
- Bad-character or propensity evidence, admitted under CJA 2003, ss. 98–113, through defined gateways and subject to a fairness review (*R v Hanson* [2005] EWCA Crim 824);
- Expert opinion, admissible if it assists the trier of fact (*R v Turner* [1975] QB 834); and
- Specially protected categories, such as sexual-history evidence (YJCEA 1999, s. 41; *R v A* (No 2) [2001] UKHL 25).

Scotland

The law remains largely common-law based, supplemented by the Criminal Procedure (Scotland) Act 1995 (CPSA 1995).

All evidence must be relevant and competent, and for conviction the essential facts (that a crime occurred and that the accused was the perpetrator) must be corroborated by two independent sources (*Moorov v HM Advocate* (1930) JC 68; *Fox v HM Advocate* (1998) JC 94).

Hearsay is generally inadmissible but permitted under specific statutory exceptions (CPSA 1995, s. 259).

Confessions are admissible only if voluntary (*Chalmers v HM Advocate* (1954) JC 66).

Restrictions on sexual-history evidence are contained in CPSA 1995, ss. 274–275, as amended by the Sexual Offences (Procedure and Evidence) (Scotland) Act 2002.

Northern Ireland

The structure largely mirrors that of England and Wales. Hearsay and bad character are governed by the Criminal Justice (Evidence) (Northern Ireland) Order 2004, and confessions by the Police and Criminal Evidence (Northern Ireland) Order 1989 (PACE (NI)).

2. Principles of Judicial Evaluation

Across the UK, judges act as gatekeepers to ensure that only relevant, reliable, and fair evidence is placed before the jury.

England and Wales

Relevance is the threshold test (DPP v Kilbourne [1973] AC 729).

Reliability is assessed through procedural compliance (e.g. PACE Codes of Practice), and fairness underpins every decision (PACE, s. 78).

These principles are replicated in Northern Ireland under the PACE (NI) Order 1989, arts. 74–78.

Scotland

The approach is similar but grounded in common law. Evidence must be both relevant and fairly obtained, per *Lawrie v Muir* (1950) JC 19, which remains the leading authority on fairness.

The corroboration rule operates as a unique evaluative filter: the judge must ensure there is legally sufficient, corroborated evidence before a case can be left to the jury.

In all jurisdictions, expert evidence is admitted only if it assists the court and rests on reliable principles (*Davie v Magistrates of Edinburgh* (1953) SC 34; Criminal Practice Directions 2023, Ch. 7).

3. The Regime for Exclusion of Evidence

While exclusion mechanisms vary, they share the purpose of protecting trial fairness.

England and Wales

- PACE s. 76(2) requires exclusion of confessions obtained by oppression or unreliability.
- PACE s. 78 grants a discretion to exclude any prosecution evidence if its admission would adversely affect the fairness of proceedings (*R v Khan* [1997] AC 558; *R v Looseley* [2001] UKHL 53).
- The CJA 2003 adds powers to exclude hearsay (s. 126) and bad-character evidence (s. 101(3)).

Scotland

Exclusion is governed by the common-law fairness test in *Lawrie v Muir*: evidence obtained irregularly may be excluded if admitting it would offend justice, though illegality alone does not automatically render it inadmissible.

Confessions not given voluntarily are inadmissible, and corroboration remains essential to evidential sufficiency.

Northern Ireland

The PACE (NI) Order 1989, arts. 74–78, provides equivalent powers to those in England and Wales, while the Criminal Justice (Evidence) (Northern Ireland) Order 2004 replicates the hearsay and bad-character regimes.

Conclusions

Country features

In **Belgium**, the evidentiary system is built on the principle of freedom of evidence, where any relevant material is admissible, tempered by judicial discretion. The Antigoon ruling established a pragmatic exclusionary rule: unlawfully obtained evidence is admissible unless null, unreliable, or compromising fairness. The **Netherlands** applies a “closed system of proof”, limiting admissibility to five lawful categories, with modern evidence routed through them. While formalistic, judges enjoy wide discretion in weighing evidence, and convictions require both lawful proof and judicial conviction. Exclusion under Article 359a CCP is pragmatic, offering remedies from sentence reduction to exclusion. **Spain** follows the principle of free proof but strictly excludes evidence obtained in violation of fundamental rights, extending to derivative evidence under the “fruits of the poisonous tree” doctrine. Judicial discretion is framed by the presumption of innocence, requiring convictions to rest only on lawfully obtained proof.

Romania adopts an open evidentiary framework, with proof “beyond any reasonable doubt” as the standard. Courts must weigh both incriminating and exculpatory evidence. Unlawfully obtained evidence is inadmissible, especially where privacy or judicial safeguards are breached. **Italy** combines a closed list of typical evidence with flexibility for “atypical” forms if reliable. Convictions require proof that is “grave, precise, and consistent”, with the overall threshold of beyond reasonable doubt. The exclusionary rule of *inutilizzabilità* (which means that the evidence cannot be utilised) has been broadened to strengthen protection of rights. **Greece** also uses an open system, with free evaluation and reasoned judgments. Evidence obtained in violation of constitutional rights is generally inadmissible, though exceptions based on proportionality allow its use to prevent miscarriages of justice. In the **United Kingdom**, evidentiary rules are shaped by the common law and statute, grounded in the principles of relevance, reliability, and fairness. England and Wales and Northern Ireland operate codified statutory frameworks under the Police and Criminal Evidence Acts and the Criminal Justice Acts, combining flexible admissibility with discretionary exclusion where fairness demands it. Scotland retains a distinct common-law model, marked by the corroboration requirement and the *Lawrie v Muir* fairness test. Across all UK jurisdictions, unlawfully obtained evidence may still be admitted if fairness permits, reflecting a pragmatic balance between truth-finding and due process.

A comparative outlook

A comparative analysis of these seven countries reveals a clear **dichotomy between systems with a closed list of admissible evidence** (the Netherlands, and to a degree, Italy) and **those with a broad, open approach** (Belgium, Spain, Romania, Greece and the UK). The Dutch model stands out for its formality in what counts as legal proof, while the Belgian model is notable for its liberal admissibility combined with a lenient exclusionary rule. Similarly, there are **variations in the**

exclusionary rules. Spain and Romania adhere to a strict approach, invalidating evidence obtained in violation of fundamental rights, with Spain extending this to the “fruits of the poisonous tree.” Greece, while similarly strict on constitutional violations, offers a pragmatic exception when necessary to prevent a miscarriage of justice. The United Kingdom, like Belgium, adopts a **flexible and fairness-oriented standard**, where judicial discretion ensures that evidentiary irregularities are evaluated in light of their impact on trial fairness rather than by automatic exclusion.

Despite these differences, a common thread unites these systems: **the principle of free judicial evaluation** and **the ultimate standard of the presumption of innocence**. Whether in a closed or open system, the judge's role is not just to passively accept evidence but to actively and rationally weigh its value. This highlights a shared European commitment to the idea that a criminal conviction must be based on a reasoned conviction, grounded in evidence that is not only probative but also obtained and presented in a manner that respects the fundamental rights of the accused and procedural fairness.

The issue of **exclusion of evidence** is a key barrier emerging from the review presented. The EC-DRL framework in this context can be seen as the central mechanism for resolving this structural challenge. Furthermore, the **heterogeneity of evidentiary systems** identified in this review demonstrates the complexity of achieving a unified standard of admissibility for citizen-generated evidence across the ENFORCE consortium's jurisdictions. This issue should be addressed not only and not necessarily as potential barrier, but rather as an opportunity, i.e. it should be ensured that local data collection protocols **accommodate these specific national legal variations**.

3.2.3 Insights from the literature review (T2.3)

Background

The following section analyses the results of the literature review performed under T2.3, which focused on scientific studies related to CS for environmental compliance with the aim to define the state of the art for the use of CS for compliance assurance, in terms of relevant studies on existing cases, on applicable legislation, on barriers and needs, on data readiness levels. The review encompassed studies on CS for environmental compliance in the EU priority areas of biodiversity, pollution, farming and illegal logging. The sources cited in the literature review (and in the References – Section 8 of this document) that follows represent at least 1/3 of the total sources collected in the Excel Table for the review performed ([link](#)).²⁴ These sources have been selected here as they represent the most relevant sources for ENFORCE purposes.

Relevant legislation

Outline of the section

²⁴ See <https://doi.org/10.5281/zenodo.17902173>

This section outlines the legal framework on which environmental compliance is based, in order to demonstrate how CS - including also civic environmental monitoring²⁵ - can be an effective tool for ensuring environmental compliance, both in court and in law enforcement. In this regard, the following paragraphs aim to provide an overview of the main regulations referred to in the bibliographical sources. The analysis is informed by the literature review performed and is structured on the basis of the environmental matrices most affected by pollution and most frequently addressed in the research and individual case studies.

Legal framework on air quality

A first relevant theme in the literature is the reference to national and EU/international legal frameworks on air quality. Within the European Union (EU) system, the regulatory framework for air quality is based on two key Directives of the European Parliament and of the Council: Directive 2008/50/EC and Directive (EU) 2024/2881, which entered into force in December 2024 and repeals the previous directive as of December 2026 (Clean Air for Europe Directive).

The main and most significant difference between the two Directives lies in the more rigorous and stringent standards promoted by the Directive (EU) 2024/2881, which sets more ambitious and strengthened climate-alternating emission reduction targets in line with the latest World Health Organization standards (European Parliament and Council, 2024). Among the responsibilities of each Member State, the Directive of 2024 requires the definition of short-term action plans and roadmaps for air quality, complying with stricter limit values in order to reduce average exposure to pollutants that have a negative impact on the environment and human health. To achieve these objectives, this Directive emphasises the need for more transparency and therefore the active participation of the public, who must be adequately and promptly informed. This is a key aspect for ENFORCE.

In this legal context, CS can be interpreted as a parallel but complementary tool to institutionalised control models, especially given that CS initiatives are able to provide granular, real-time data and can fill governments and competent authorities' reporting gaps (Berti Suman, 2024). Previous research by the cited author investigates how grassroots-driven environmental monitoring initiatives – “citizen sensing” – represent a civil society response to the risks of environmental pollution to human health and, therefore, a practice through which “sensing citizens” claim their right to clean air and, more generally, their “rights in action” (Berti Suman, 2021 b).

The study by De Craemer et al. (2020) provides empirical support for a statistical model-based approach that overcomes the structural limitations of large-scale nitrogen dioxide (NO₂) measurements collected by citizens. In this way, the authors aim to optimise sampling campaigns by demonstrating how they can provide direct information for air quality assessments, as they

²⁵ Defined as “the use by ordinary people of monitoring devices (e.g., sensors) or their senses (e.g., smell, hearing) to detect environmental issues” (Berti Suman, 2024, p. 8). Civic environmental monitoring emphasizes the ‘observational’ and often systematic nature of the practice. When it is also accompanied by data analysis using a scientific approach, the broader CS practice manifests.

generate spatially dense datasets that complement data from the sparse reference network operated by environmental agencies.

In recent years, a trend has emerged in European Union case law recognising individuals' substantive right to clean air and attributing validity and reliability to data collected by citizens in the framework of CS projects (Misonne, 2020). However, Tubridy et al. (2022) point out that, although citizen air monitoring can improve environmental justice by revealing localised pollution patterns overlooked by official bodies, not all CS models are inherently fair. In fact, in their Dublin case study, they note that the dominant model tends to frame CS as a tool for raising awareness and influencing individual behaviour, rather than as a means of generating knowledge that could shape new regulations or policies. Consequently, it is important to reflect on the fact that grassroots-driven monitoring should not risk amplifying existing social and economic inequalities but rather ensure an inclusive and transparent alternative that promotes participation in decision-making processes as enshrined in the Clean Air for Europe Directive. Furthermore, there is a need to understand the purpose behind CS activities and openly disclose situations of conflict of interest or risk of biases in gathering or analysis the data, if any.

Legal framework on water quality and use

In the EU legislative context, water quality and human consumption are regulated by two main directives, as the studies analysed suggest. The Water Framework Directive (WFD) - Directive 2000/60/EC - establishes a legal framework for the protection and conservation of all water bodies, setting as its fundamental objective the achievement of the “good status” in terms of chemical, biological and ecological quality for all surface waters, coastal waters and groundwater, and requiring the implementation of river basin management plans, water status monitoring and public participation (European Parliament and Council, 2000). Related to water protection, worth citing is also the Groundwater Directive (2006/118/EC) which sets the detailed procedures for meeting the WFD's environmental objectives for groundwater quality. Furthermore, in 2020, the European Parliament and the Council of the European Union adopted Directive (EU) 2020/2184 with the aim of protecting human health from the adverse effects of contamination of water intended for human consumption, thereby setting strict microbiological and chemical parameters and establishing monitoring programmes for risk assessment and management.

Also worth noting is the recently recast Urban Wastewater Treatment Directive (EU) 2024/3019, which strengthens wastewater management by expanding treatment obligations to smaller agglomerations, tightening nutrient removal requirements, introducing advanced treatment for micropollutants, and supporting circular-economy and climate goals through energy-efficient, low-emission wastewater treatment. Collectively, these directives work to reduce pollution, enhance ecological resilience, and ensure the long-term health of Europe's waters.

To safeguard water quality for recreational use, the Bathing Water Directive (2006/7/EC) establishes monitoring and management measures aimed at ensuring that bathing waters remain clean and safe. Its environmental objective is to improve microbiological quality, reduce pollution from wastewater and agricultural runoff, and provide a high level of public health protection while

maintaining ecologically healthy coastal and inland bathing sites. Also, the Marine Strategy Framework Directive (2008/56/EC) provides a comprehensive approach to safeguard Europe's marine environment. Its environmental objectives aim to achieve Good Environmental Status in EU seas by reducing pollution—including chemical contaminants, marine litter, and noise—protecting biodiversity and habitats, preventing ecosystem degradation, and ensuring that human activities in marine waters remain ecologically sustainable.

The analysis conducted by Grumiero et al. (2025) investigates the opportunities for CS to increase its positive impact in the freshwater sector, as well as the possibilities for achieving the objectives of the WFD and the Sustainable Development Goals (SDGs). From this perspective, the study highlights the need to strengthen collaboration between CS programmes and environmental agencies at national and subnational levels, improving the synergy between official and civic data.

A study conducted by König et al. (2021) examines whether data collected by citizens can truly complement the official data processing network for water quality monitoring. The results show that, despite the inherent challenges of the phenomenon, through the development of statistical tools for CS data validation by the same CS communities, peers and/or experts, participatory science can contribute significantly to the evidence base needed for the design of water protection regulations and policies.

Collins et al. (2023) summarised the approach to CS taken by the Rivers Trusts in the United Kingdom, which is focused on water quality monitoring in freshwater environments. This practice has greatly increased public consciousness of river health, which is an important achievement given that citizens' perceptions of natural environments, the water they consume, and their resulting levels of knowledge and awareness are fundamental issues for CS (Blidar et al., 2023; Bouriaud, 2014). It has also directly triggered concrete actions based on citizen involvement, the empowerment of local communities, improved communication with key stakeholders and the publication of the data collected in open access formats available to the public (Collins et al., 2023).

Another concrete example of CS leading to environmental action, also from the United Kingdom, is the Riverfly Monitoring Initiative (RMI), pioneered by the Riverfly Partnership. Project volunteers are trained to take standardised samples of freshwater invertebrates in a matter of minutes and to make an assessment of water quality based on the abundance of key pollution-sensitive taxa. Data produced through this programme have also been useful in evaluating the effectiveness of river restoration actions, as well as demonstrating how widespread citizen involvement can succeed in shaping a programme that integrates the work of statutory authorities (Brooks et al., 2019).

Legal framework on biodiversity conservation and protection

National and EU/international legislation on biodiversity protection was often referred to in the literature surveyed. Directive 2009/147/EC (Birds Directive) – initially adopted in 1979 and later amended in 2009 – and Council Directive 92/43/EEC (Habitat Directive) of 1992 were identified by several studies as two fundamental directives in the legal framework governing the conservation of natural habitats and the protection of wild animal species. Specifically, the

Habitats Directive aims to safeguard biodiversity through measures to conserve or restore natural habitats and wild fauna and flora in Europe. To this end, the Directive also establishes the Natura 2000 network, an ecological network of sites such as Special Areas of Conservation and Special Protection Areas for the protection of habitats and species linked by ecological corridors (Council of the European Communities, 1992). The Birds Directive was also mentioned. It focuses on the protection, management and control of all wild bird species in Europe that are threatened by the loss of their natural habitats (European Parliament and Council, 2009). Focusing on marine biodiversity, it is relevant once again the the Marine Strategy Framework Directive (2008/56/EC) which sets a comprehensive framework for safeguarding Europe's marine environment.

Once again, the contribution that CS can make to the collection of data concerning the maintenance of a satisfactory state of ecosystems is remarkable. The analysis conducted by Norman (2018) describes the emergence of a new model within the Australian Environment Protection and Biodiversity Conservation Act of 1999, relating to the possibility for citizens to participate in the Environmental Impact Assessment (EIA), providing legislative and political support for involvement in monitoring compliance with the various stages of project assessment and approval. Among other regulations, the Nature Conservation Act of 2014 recognises the potential involvement of community organisations in monitoring activities. Therefore, this case highlights the ability of CS to identify environmental infringements and risks in a timely manner, while also improving the transparency and legitimacy of decisions.

Access to information, access to justice and public participation

While the analysis in the previous paragraphs focused on single environmental matrices, the following paragraph will specifically address the issue of every people's right to access environmental information, ensuring public participation in environmental decision-making processes and guaranteeing fair access to justice when the above right is denied. The section is also informed by clusters emerging in the literature analysed.

The 1998 Aarhus Convention establishes three fundamental pillars for democratic environmental governance: access to information, public participation in decision-making processes, and access to justice in environmental matters (United Nations Economic Commission for Europe, 1998).

In this context, Berti Suman (2021a) analyses citizen sensing as a practice that can find legal legitimacy in light of the Aarhus framework, as it strengthens citizens' right to be informed and to contribute to environmental decisions, especially when official channels are insufficient or lack transparency, and acts as a catalyst for the implementation of the Aarhus principles by providing data that can trigger legal proceedings to promote environmental compliance and enforce environmental rights (Berti Suman, 2024).

A practical application is illustrated in the study on “civic sentinels”, i.e. local citizens acting as alerts reporting environmental problems in their area: here, data collected by the community against oil pollution has made it possible to fill information gaps, support claims and influence the political agenda, demonstrating that adequate access to environmental information is an essential condition for achieving environmental justice (Berti Suman, 2022).

In the European context, the January 2025 ruling of the European Court of Human Rights in the case of *Cannavacciuolo and Others v. Italy* is a prime example of the legal importance of the principles of the Aarhus Convention and the need for their application. In this legal case, Italy was found guilty of violating Article 2 of the European Convention on Human Rights by failing to fulfil its positive obligations under that article relating to the protection of the right to life of the inhabitants of the “Terra dei Fuochi” area. Specifically, the authorities failed to take adequate measures to prevent the risks arising from the illegal disposal and incineration of toxic waste, despite having been aware of the danger for years, and failed to provide the residents concerned with timely information enabling them to protect themselves. In particular, with regard to issues relating to the pillars of the Aarhus Convention, the judgment highlights a breach of the obligation to ensure public access to environmental information, a general lack of preventive information and the absence of a coherent and centralised public information system that provides citizens with reliable and accurate data on environmental risks.

Analyses in non-European contexts also underline the centrality of these principles: Mulyana and Kurniati (2024), reflecting on the Indonesian experience, observe that public participation in environmental issues, such as in the Environmental Impact Assessment (EIA) process, often remains limited due to institutional, legal and cultural barriers. The authors suggest that in order to fully comply with the objectives of the Aarhus Convention, it is necessary to strengthen the legal infrastructure, capacity building and community empowerment. Only in this way will it be possible to substantially improve the quality and effectiveness of environmental governance in the Indonesian context.

Relevant barriers faced by Citizen Science for environmental compliance

Despite growing recognition of the value of CS in environmental monitoring processes and in enforcing environmental compliance, the literature highlights the persistence of structural barriers that limit its full recognition and integration into environmental governance and the legal framework.

On the economic and financial level, one of the main obstacles is the lack of sustainable and consistent funding structures. The study by Turbé et al. (2019) shows that only 24% of projects have sufficient resources over time, highlighting minimal civil society involvement and reluctance on the part of policymakers, especially at the local level, to integrate civic data into the institutional framework. Added to this are the lack of funds to initiate legal proceedings in affected communities (Mulyana and Kurniati, 2024), dependence on one-off funding, which reduces sustainability, large-scale volunteer commitment and, therefore, long-term impact (De Craemer et al., 2020) and, in some cases, limited availability of technological devices, which is a real barrier to public participation (Blidar et al., 2023; Bouriaud, 2014).

Legal barriers represent a further critical issue. The acceptance of civic evidence in courts remains complex, especially when data collection relies on sophisticated techniques, which increase the likelihood of challenges by defendants, courts or authorities. However, the legitimacy of CS could be strengthened by deriving a “right to contribute environmental information” as a fourth pillar of

the Aarhus Convention, thereby recognising the valuable role of civic monitoring and “civic sentinels” (Berti Suman, 2024). Furthermore, the analysis by Berti Suman et al. (2023) highlights the need to provide clear guidelines to citizen scientists to ensure the legal compliance of their activities, as the absence of specific rules to regulate their use creates procedural uncertainty. Regulatory gaps also persist: air quality legislation does not clarify whether “modelled data” can include CS contributions, and such data are rarely integrated into compliance reports due to a lack of standards for accuracy and comparability (De Craemer et al., 2020). In some contexts, there are even restrictions arising from laws that prevent the use of CS data controlled by non-governmental bodies for political purposes (Turbé et al., 2019) or that limit public participation in procedures such as EIAs to only those communities directly affected (Mulyana and Kurniati, 2024).

On the social and psychological front, the difficulties are just as significant. CS has to deal with a “double distrust”: on the one hand, institutions tend to doubt the quality of civic data and on the other, citizens are distrustful of institutions (Berti Suman, 2021b). The scepticism of public officials tends to be based on doubts about the ability of volunteers to interpret data correctly, especially if it is collected irregularly, a condition that is difficult to balance with the need for regular sampling frequencies for reliable analysis (König et al., 2021). In essence, political reluctance to change and a lack of resources to encourage public participation (Turbé et al., 2019), unawareness and the generally low level of public awareness, starting with the communities concerned (Mulyana and Kurniati, 2024), outline the psychological challenges that CS must face in order to establish itself as a fully legitimate and effective tool in environmental governance.

Specific needs for tools and for capacity building

Across the literature, scholars converge on the idea that CS requires targeted tools and systematic capacity building in order to overcome its current limitations and fully contribute to environmental governance. Berti Suman (2024) stresses the importance of clearer judicial guidance on evidentiary standards and a formal procedural recognition of civic evidence, paired with stronger connections between civic monitoring and enforcement authorities, with research centres acting as mediators. From a rights-based perspective, Berti Suman (2021a) highlights the need for CS practitioners to understand and navigate procedural environmental rights under frameworks such as the Aarhus Convention, while her earlier work (2022) calls for legal support, trusted channels of information exchange, and safe data infrastructures to sustain civic engagement.

Similarly, Grumiero et al. (2025) emphasize strategies to build trust between regulators and citizen scientists, an issue echoed by Collins et al. (2023), who advocate both wider regulatory acceptance of civic data and affordable technical tools that empower non-specialists to monitor a broader spectrum of contaminants. On the legal–institutional side, Kasperowski et al. (2023) point to the need for greater involvement of legal practitioners—lawmakers, judges, lawyers—in shaping frameworks that are responsive to civic science practices, while Berti Suman (2021b) underlines the necessity of deepening judicial competences and applications of citizen sensing.

Other contributions focus on data quality, infrastructure, and methodological co-design. König et al. (2021) identify the need for carefully designed digital platforms that can flexibly represent empirical evidence and incorporate metadata about uncertainties, ensuring results are both meaningful and transparent. De Craemer et al. (2020) suggest longer-term deployment of passive samplers in air quality projects to reduce model uncertainty and strengthen compliance relevance.

Turbé et al. (2019) expand this agenda to the policy level, calling for standardized and interoperable data platforms, robust evaluation frameworks, and stronger mechanisms for communication between policymakers and CS practitioners, while also stressing the importance of government support, NGO leadership, and training to maintain scientific quality. Finally, Tubridy et al. (2022) highlight the role of academic and regulatory actors in supporting grassroots initiatives - both by amplifying community voices and by collaborating to interpret and validate the collected data.

Data Validation

In the literature on CS (specifically targeting CS data quality see e.g., Balázs et al., 2021; Downs et al., 2021; Stankiewicz et al., 2023), the issue of data validation and the inherent data quality highlights the persistent challenge of validating data produced by non-experts. As Berti Suman (2021a) notes, the absence of standardised protocols shared by both participants and enforcement authorities undermines the recognition of such data, pointing to the need for procedural alignment to enhance reliability. Turbé et al. (2019) offer a more optimistic view, showing that many initiatives already ensure transparency and accessibility - 91% of projects analysed provided metadata, over half made data openly available, and a large majority were reused by the scientific community - suggesting pathways to increase the credibility and usability of citizen-generated evidence. Yet, as Tubridy et al. (2022) demonstrate in the Dublin case, professionals often remain sceptical, framing CS primarily as a tool for awareness-raising rather than a provider of robust datasets.

Overall, while most projects still operate at relatively low validation processes, the literature stresses that quality assurance, standardisation, and institutional recognition are key to advancing the acceptance of CS data. The discussion encompasses several dimensions, including data quality. It reveals an emerging field.: while CS data often remains at low levels of data fit for purpose, the limited attention given to this matter in the literature is itself significant, showing that the issue is still new and requires stronger engagement from civil society and institutions. The forthcoming ENFORCE D2.3 will be focused on establishing a definition of Data Readiness Levels (DRLs) tailored to the CS perspective. This observation stands out as a key message for the ENFORCE project, underscoring the need to advance the credibility and acceptance of civic environmental data.

Additional comments

The analysis developed in this work has shown that CS is not merely a data collection tool, as it also involves validation, analysis, and visualization. It is essentially a practice that intertwines

scientific, financial, social, legal and political aspects, with the aim of strengthening environmental compliance and expanding opportunities for environmental justice for citizens.

From a regulatory perspective, CS is intertwined with the main European directives on air, (fresh and sea) water and biodiversity, as well as with the Aarhus Convention, which provides the framework for rights of access to information, justice and participation. The authors agree that these legal bases, while opening up spaces for legitimisation, require further adaptation to enhance the role of citizens in monitoring and enforcement processes (Kingston et al., 2021; Berti Suman, 2021a; Berti Suman, 2024).

The analysis of case studies, ranging from judicial and extrajudicial experiences in Europe and the United States to local initiatives in Asia and thematic projects in various countries, shows how CS can make a concrete contribution both in courts and in policy processes. At the same time, these experiences highlight the variety of approaches and results, as well as the tensions between institutions and civic actors.

In terms of barriers, the literature points to economic limitations linked to the scarcity of stable funding (Turbé et al., 2019), legal obstacles due to the difficult acceptance of civic data in official proceedings (Berti Suman, 2021a; De Craemer et al., 2020), and social challenges due to low awareness, information inequalities and mutual distrust between citizens and institutions (Mulyana & Kurniati, 2024; König et al., 2021).

Several authors have identified key needs for strengthening CS: legal and procedural recognition of civic monitoring (Berti Suman, 2022; 2024), the construction of interoperable and standardised platforms (Turbé et al., 2019), co-design processes for data collection systems and accessible technical innovations (König et al., 2021; Collins et al., 2023), as well as the crucial role of universities and research centres as mediators and facilitators (Tubridy et al., 2022). Only by responding to these needs will it be possible to consolidate CS as a tool for advancing environmental compliance assurance.

3.3 Primary data: T2.3 survey and follow-up interviews

3.3.1 Key results from survey

Background

Task T2.3 included a qualitative analysis into the challenges faced by citizens, authorities, legal experts, researchers and innovators willing to use CS for compliance assurance. In this section we describe the key results that emerged from the ‘perception analysis’ survey performed. Methodological aspects of the survey’s deployment can be found in Section 3.1 of this deliverable. 169 responses were gathered from different countries, disciplines and categories of stakeholder.

Results

Below, we offer an overview of the distribution of respondents across categories, with academia and civil society as the most represented categories of respondents. Of these, around 45% had already worked in the field of environmental compliance or in fields somehow connected. Around 35% of the respondents were very familiar with CS applied to environmental matters, whereas a 54% of the respondents were to some extent familiar with the matter, and only 12% were not at all familiar with this topic.

Q1 Do you identify as...? (just one option possible; if you believe that you represent more than one category, please choose the prevalent one)

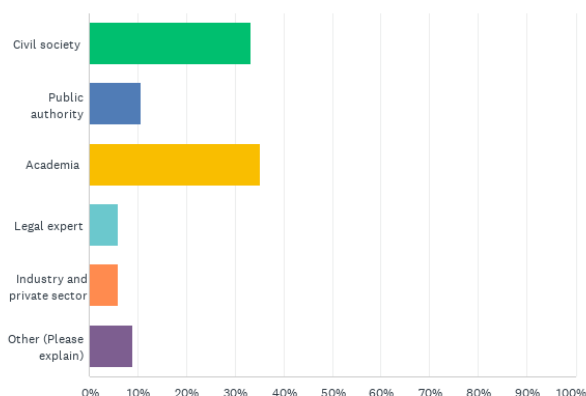


Figure 4 - Categories of respondents

An interesting majority of the respondents believe that CS could be used to support compliance with environmental law, as the figure reported below illustrates with an almost equal distribution of responses across the very convinced ones and those identifying potential with some limitations.

On the reliability of the data and information gathered through CS for compliance assurance, 65% of the respondents are positive but identify some limitations, whereas 25% of the replies are very positive. The negative replies also in this case are an insignificant percentage. On the reliability of CS data and information for increasing public awareness on environmental matters, 55% of the respondents are very positive, whereas 39% are positive but identify some limitations. The negative replies are none.

Q4 Do you believe that citizen science could be used to support compliance with environmental law?

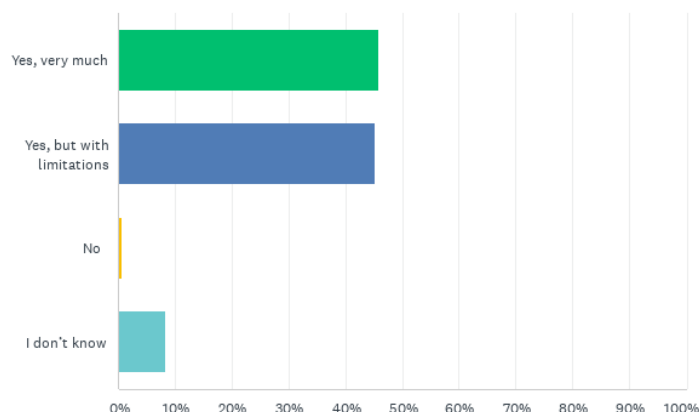


Figure 5 - Attitudes towards the use of citizen science for compliance

59% of the respondents consider CS data complementary to that gathered by official authorities for environmental compliance, and 34% are positive to this statement but identify some limitations. The negative replies are below 1%. Interestingly, the majority of respondents (61%) believe that CS can be effectively used to bring evidence in court to support environmental compliance, whereas a 7% disagree and a notable 32% does not know how to answer this question, showing some persistent uncertainty in the field.

A tricky question was the next one, posed as a negative question, i.e., “citizen science cannot be mobilised to offer evidence in court but can just be used as an alert to enforcement authorities such as the police”. Here the replies are almost equally distributed between the “yes, very much” (34%), “yes, but with limitations” (29%), and “no” (30%) with a small percentage of uncertain respondents (7%). This suggests that some respondents ‘fell’ in the trick of the question and contradicted themselves in responding to this question.

An interesting overview of perceived barriers is delivered by the responses to the question on the main obstacles for using CS for environmental compliance. The respondents were asked to rank a series of barriers from 1 to 5, where 1 is the minor obstacle and 5 is the major obstacle. The figure below shows the distribution of the ranking across the listed barriers.

Q10 What are the main obstacles for using citizen science for environmental compliance?
Rank them from 1 to 5, where 1 is the minor obstacle and 5 is the major obstacle.

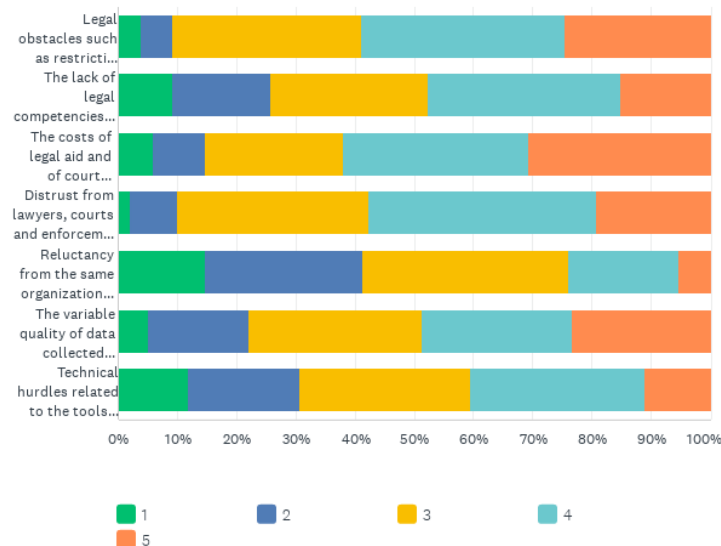


Figure 6 - Ranking of barriers to the use of citizen science for compliance

The table below instead indicates the weighted average of the ranking per barrier. The three barriers ranking higher are the costs of legal aid and of court proceedings, legal obstacles such as restrictions to the admissible evidence imposed by national procedural laws, and distrust from lawyers, courts and enforcement authorities towards CS.

Table 8 - Ranking of the barriers to the use of citizen science for compliance assurance

	1	2	3	4	5	TOTAL	WEIGHTED AVERAGE
Legal obstacles such as restrictions to the admissible evidence imposed by national procedural laws	3.97% 6	5.30% 8	31.79% 48	34.44% 52	24.50% 37	151	3.70
The lack of legal competencies within the citizen science community	9.27% 14	16.56% 25	26.49% 40	32.45% 49	15.23% 23	151	3.28
The costs of legal aid and of court proceedings	6.00% 9	8.67% 13	23.33% 35	31.33% 47	30.67% 46	150	3.72
Distrust from lawyers, courts and enforcement authorities towards citizen science	1.99% 3	7.95% 12	32.45% 49	38.41% 58	19.21% 29	151	3.65
Reluctancy from the same organizations promoting citizen science	14.67% 22	26.67% 40	34.67% 52	18.67% 28	5.33% 8	150	2.73
The variable quality of data collected through citizen science	5.19% 8	16.88% 26	29.22% 45	25.32% 39	23.38% 36	154	3.45
Technical hurdles related to the tools used by citizen science	11.76% 18	18.95% 29	28.76% 44	29.41% 45	11.11% 17	153	3.09

A large majority, i.e., 70 % of the respondents, believe that programs offering capacity building on CS are needed by law enforcement actors. Around 40% of the respondents agreed to be contacted for a follow-up interview of 1 hour maximum to explore further some of the aspects emerged in this questionnaire, and indicated their contact for doing so, as detailed in section 3.3.2.

The open questions to the survey

The survey also included three open questions. Below we indicate the questions and outline the relevant thematic clusters that emerged from these open fields.

- **Question 11 - Can you mention one other barrier that limits the use of citizen science for environmental compliance?**

A total of 107 valid responses were analysed to identify recurring themes and concerns. The analysis revealed 10 main thematic clusters²⁶ (mentioned by 5 or more respondents), each capturing a specific type of barrier that stakeholders perceive as limiting the uptake and integration of citizen science (CS) in environmental compliance processes:

1. Institutional distrust and resistance (20 mentions)

Respondents frequently cited a lack of trust or openness from public authorities, legal professionals, courts, and scientists toward CS. Barriers include institutional reluctance to accept non-institutional data, perceived threats to institutional authority, and lack of recognition of CS evidence in legal or administrative settings.

2. Data quality and reliability (19 mentions)

Concerns about data credibility, bias, inconsistency, and lack of validation protocols were widely mentioned. Respondents stressed the need for standardized methodologies, quality control procedures, and expert review to ensure that CS data can be used reliably in formal contexts.

3. Gaps associated with the legal and policy framework (18 mentions)

Many respondents noted that the absence of clear legal frameworks, standardized procedures, and regulations hampers the admissibility and operational use of CS data in compliance cases. Some referred to the lack of legal robustness and the challenge of translating grassroots data into legally actionable evidence.

4. Lack of awareness and education (16 mentions)

A lack of environmental knowledge, legal literacy, or awareness of citizen rights among potential participants was identified as a significant barrier. Respondents emphasized the need for outreach, training, and educational programs to empower citizens.

5. Citizen motivation and engagement (7 mentions)

²⁶ It should be noted that some of the clusters listed below could also be regarded as subsets of other clusters, for example cluster 5 could be regarded as a sub-set of cluster 4 and cluster 10 as a sub-set of cluster 9. However, for the relevance of these sub-clusters to our overall analysis, we decided to single out these clusters as standalone themes.

Several responses pointed to declining or inconsistent engagement, limited motivation, or low long-term commitment among citizens. This includes challenges in sustaining volunteer involvement and ensuring representativeness.

6. Political and economic pressure (7 mentions)

Respondents highlighted the risk of political or corporate backlash against CS actors who monitor sensitive sites. Barriers include lobbying, intimidation, bureaucratic obstruction, and threats against individuals or communities.

7. Operational and resource limitations (6 mentions)

Barriers related to funding, staffing, scalability, and long-term sustainability were frequently mentioned. Projects relying solely on volunteer work or short-term grants are seen as difficult to maintain.

8. Cultural and philosophical barriers (6 mentions)

Some participants pointed to deeper cultural or epistemological biases hampering the reliance on CS for compliance assurance. These biases include resistance to “spying” in certain societies, or the devaluation of local or experiential knowledge in favour of institutional expertise.

9. Technical and infrastructural barriers (5 mentions)

Challenges include lack of access to equipment, inadequate calibration of low-cost sensors, limited technical support, and incompatibility of CS standards with those standards commonly used by authorities.

10. Data interoperability and integration (5 mentions)

The lack of technical compatibility between CS data and official datasets, or the absence of mechanisms to integrate CS data into public systems and workflows, was also cited as a significant obstacle

- **Question 12 - Can you mention one opportunity to boost the use of citizen science in environmental compliance?**

A total of 105 valid responses were analysed to identify recurring opportunities perceived by stakeholders. The analysis revealed 10 main thematic clusters (mentioned by 5 or more respondents), that reflect practical, institutional, social, and technological levers for enhancing the role of CS in environmental compliance.

1. Scientific recognition and legitimacy (37 mentions)

Respondents emphasized the need for greater recognition of CS as a legitimate scientific practice. This includes opportunities to improve the status of CS data through transparent methodologies, expert validation, and integration into evidence-based frameworks. Some highlighted the importance of giving citizen scientists roles in curating data and contributing to formal investigations.

2. Education and awareness raising (18 mentions)

Many respondents mentioned the importance of building awareness and knowledge among the general public, students, and specific user groups. Initiatives such as school-based programs, environmental education campaigns, and tailored training were seen as powerful ways to strengthen engagement and understanding.

3. Integration with official systems (14 mentions)

Respondents identified the formal incorporation of CS into governmental monitoring and enforcement systems as a major opportunity. Suggestions included creating collaboration frameworks with authorities, aligning data collection with institutional standards, and ensuring mutual trust between public bodies and citizen scientists.

4. Technology and digital tools (14 mentions)

The role of digital innovation emerged as a key enabler. Tools such as mobile apps, AI-powered systems, sensors, and user-friendly platforms were frequently cited as means to simplify participation, increase accuracy, and reduce costs.

5. Environmental justice and local knowledge (11 mentions)

CS was seen as a strategy to promote environmental justice by amplifying local struggles and integrating community knowledge into decision-making. Opportunities include leveraging place-based activism and solidarity to bring visibility to underserved areas or pollution hotspots.

6. Standardization and quality assurance (11 mentions)

Developing clear standards and protocols for CS data collection was seen as a necessary step toward broader institutional acceptance. Referencing established frameworks (e.g., reliance on international and national standards for air quality sensors) was noted as an opportunity to improve credibility and legal viability.

7. Legal and policy support (9 mentions)

Opportunities were seen in the explicit recognition of CS in national or EU environmental laws, inclusion in compliance frameworks, and use in legal processes such as strategic litigation. Legal acknowledgment would improve data usability and formal relevance.

8. Citizen engagement and empowerment (9 mentions)

Respondents proposed enhancing citizen participation by making them feel more involved in environmental governance. Training, motivation, accessible tools, and direct links with local contexts were highlighted as engagement boosters.

9. Cost effectiveness and funding (7 mentions)

CS offers a cost-efficient alternative or complementation to formal monitoring. Respondents noted the potential to reduce enforcement costs but also stressed the need for accessible funding and resources to support grassroots efforts.

10. Partnership with NGOs and networks (5 mentions)

The role of civil society organizations and international networks was seen as key to scaling and sustaining CS. Respondents called for alliances between NGOs, community groups, and researchers to amplify voice, visibility, and impact.

- **Question 14 - Is there anything that you would like to add?**

Out of 168 respondents, 25 provided valid open comments. These responses offered clarification, critique, or suggestions that complement the structured survey questions. The comments revolve around two main thematic clusters:

1. Data quality and scientific standards (18 mentions)

Many respondents reiterated the importance of data quality, standardization, and validation for CS. They emphasized that all CS data must be fit-for-purpose, traceable, and scientifically sound. Some raised concerns about scepticism among scientists and the challenges of aligning CS data with established protocols.

2. Need for legal and institutional support (9 mentions)

Respondents called for stronger institutional frameworks to support CS. Suggestions included legal recognition, formal certification systems, and partnerships with regulatory or scientific bodies to ensure the legitimacy of citizen-contributed data.

3.3.2 Key results from interviews

Background

The data collected throughout the survey was complemented by the deployment of 3-5 expert interviews from partners' networks and stakeholder mapping in each of the countries involved in the consortium, to contribute to the validation of the findings from desk research and from the perception survey. Around 40 interviews have been performed, mostly remotely, for a duration of around 1 hour each. Our standard approach has been to cite only role, position and country – where relevant – of the person interviewed unless the person explicitly asked to be cited with their name. In this case, we do so in footnote.

We decided to balance the outcomes of the perception survey with 3-5 expert interviews in each ENFORCE country. Part of the interviewed experts have been selected through one of the last questions of the survey asking for the willingness to be contacted for a follow-up interview (if so, the respondent had to indicate a preferred contact). Around 40% of the respondents agreed to be contacted for an interview. In addition, we balanced nationality and expertise with integrative interviews to contacts in our stakeholder networks beyond the respondents to the survey. Below, we discuss the main outcomes of the interviews. Nationality represented all countries in the ENFORCE consortium (Italy, Austria, The Netherlands, Romania, Belgium, Greece, Spain, United Kingdom, Germany, Czech Republic).

Respondents were distributed across the following categories:

- Civil society
- Representative of an authority
- Legal expert
- Innovator in the tech sector
- Other (often researchers and policymakers)

Respondents turned out to have different degree of familiarity with CS and with environmental compliance, ranging from expert level to none.

Below we report some trends that emerged from the data analysis which has been performed across countries and across categories of respondents to identify recurring themes but also outliers.²⁷

Thematic clusters

- *Respondents' beliefs on using citizen science to support environmental compliance offering reliable and complementary evidence to official data*

The majority of respondents agreed that citizens can collect data in coordination with authorities, complementing official evidence. The complementary role for CS, embedded within a broader evidentiary framework, was stressed several times. CS can integrate official monitoring, especially for awareness raising and identifying pollution hotspots. In other cases, evidence from civil society can fill official data gaps. Properly validated civic data stemming from low-cost sensors can fill gaps in official monitoring networks and act as early indicators for enforcement authorities. Citizen engagement was said to often lead to political attention and sometimes even court involvement, shifting the burden of proof onto polluters. In other cited cases, further professional research was ordered by an independent agency to complement the civic data presented in court.

Without generalization, respondents from the private forestry sector in Romania, especially the ones involved in the implementation of forest management, consider that while CS can play a role in the environmental dialogue, it should not be relied upon for enforcing or supporting environmental compliance. This view stems from concerns about its potential to distort the broader positive impact of forests across sectors, as well as the lack of trust among foresters and their representative organizations. Additionally, strong lobbying by environmental NGOs is seen as having a disruptive influence on policymaking. Instead, CS is considered by the respondents to be better suited for participatory processes that foster mutual understanding rather than conflict. These views were contradicted by another Romanian respondent, a representative of an environmental NGO, who noted that CS and community initiatives are critical for awareness-raising, mobilizing residents, and applying pressure on policymakers. When structured and validated (e.g., through specialist support and partnership with authorities), citizen-led efforts can influence compliance processes and policy changes, noted the person. Formalizing citizen groups and leveraging specialist expertise were seen as key for impactful action. Overall, these two

²⁷ All the scripts from the conducted interviews can be made available upon request in anonymized form.

opinions, coming from forest owners, reflect a strong conflict embedded in the society as regards limits of interference with private property no matter if is about the regulatory authority or the environmental NGO. This tension, currently debated in the Romanian context, can also be relevant for other local contexts in the ENFORCE countries.

An innovator from Belgium also proved to be an outlier noting that CS reports “are per definition not evidence” and authorities will have difficulty listening, especially local governments. The person was more optimistic in terms of the attention that courts could give to these reports. Also in the UK, a respondent from civil society noted that there is little support for (or trust in) CS from local authorities.

A respondent pointed to a spectrum of civic contributions with some CS being more observational and informal, while other contributions are very rigorous. Understanding and acknowledging those differences was seen as key to making the best use of it. Under this cluster, we cite a noteworthy quote from a representative of an environmental authority in the UK:

“There’s huge potential for citizen science to act as both an early warning system and a long-term monitoring tool. These groups are out there regularly and often have a much deeper day-to-day awareness of what’s normal and what isn’t in their local environment. We’ve been working to better understand where citizen science can offer complementary evidence to the EA’s [Environment Agency’s] official data. For example, we’ve explored how citizen data could be used within our weight of evidence approach — where multiple lines of data help us understand environmental quality. (...) Citizen science is often key to identifying repeat offences or slow, ongoing issues that might not otherwise reach our threshold for response. Their consistency and proximity to the environment make them invaluable in that regard. (...) Finally, I think we need to be clearer that citizen science isn’t about replacing regulatory functions — it’s about making them better. It can help us spot problems earlier, gather intelligence more widely, and involve communities more directly in protecting their environment. But it needs to be easy to contribute, and it needs to feel like it matters.”

A judge and prosecutor from Italy agreed that CS can be used to support environmental compliance mostly through prevention (and for this, it is important to build a relationship with prosecutors and police forces in order to gain their trust and attention) and collaboration (with environmental protection authorities, otherwise there is a risk that the other party will contest the results). The person noted that “monitoring is often a way of putting pressure on institutions to launch independent investigations”.

A legal expert from Belgium noted that CS can be very effective in supporting compliance especially for certain types of environmental crime, such as biodiversity-related offences, which require physical presence on the ground to be detected. Individuals who are regularly out in the field, whether birdwatching, recording plant species, walking their dogs, or simply enjoying nature, can play a key role. Second, CS can be instrumental in identifying pollution or illegal waste disposal. The person pointed to instances where chemical waste or drug-related dumping has been discovered simply because observant individuals happened to be present in those remote areas. The person also noted that “the line between CS and pure citizen environmental complaint is often a blurred/fuzzy one: both involve observation and documentation. The difference perhaps

lies in the intent or the organisation behind the act—but in practice, they can be closely linked. In many cases, the data gathered by citizens can later be picked up by NGOs or public authorities. The distinction between the citizen as data collector and the expert as data interpreter becomes important here.”

A lawyer from Belgium shared a different position. The person noted “I fully respect CS work and everybody's work in that field, but I believe it gives the false impression that you can solve that problem with that kind of therapy. And that is not the case. I have the feeling that CS can actually stall formal action because, in the case of pollution, the industry could use it as an excuse to say ‘look, there are solutions, and everybody is looking for solutions...’. But the problem is too severe to be solved by methods like that.”

- *Experiences shared by the respondents in terms of CS being used to support environmental compliance, including making reference to actual cases*

Most of the respondents knew cases of CS being used in research and advocacy but not for compliance assurance. Some respondents noted that the citizen scientists have participatory rights in the environmental impact assessment hearings under certain conditions. As such, they may submit evidence (such as sightings of protected animal species on a plot of land which should be developed). However, they usually contract a technical expert or specialist to give their claims and collected evidence more weight in the judicial procedure. In court, someone who enjoys a certain status, like an expert, is more likely to be taken seriously when submitting CS generated data.

There are cases of “Citizen Initiatives” in Austria, which tend to be successful to stop construction projects threatening endangered species. These cases have also relied on CS data.

Citizen sensing studies, which utilize low-cost sensors (e.g., particulate matter caused by wood burning) validated with official measuring equipment, produced credible evidence and media attention in the Netherlands, even resulting in a court case. Judges accepted citizen-generated analyses as sufficient to initiate further professional investigation or shift the burden of proof to the alleged polluters.

Data sets produced are currently not used directly as legal evidence of environmental crimes in Germany – for example around biodiversity losses – but could indicate areas where potential infractions (like habitat destruction) may be occurring. Also in Germany, examples such as the mosquito atlas initiative, which identified new mosquito species, and the monitoring of birds for agricultural indicators in a Europe-wide network have been valuable cases in support of compliance assurance.

Community-led initiatives that involve municipalities, public health agencies, research institutes and citizens to measure and improve air quality also worked effectively in the Dutch context. These included awareness-related projects: “Snuff Bikes” initiative (school-level awareness), fireworks ban (monitoring), environmental and traffic zones, air pollution and deforestation (monitoring and partial enforcement).

The experience with citizen scientists labelling underwater images to detect threats for marine species due to waste was indicated. This data supports AI-based automated categorisation, improving monitoring capabilities, and can be used for detecting illegal sea waste disposal and ghost fishing gear. However, it was noted that direct enforcement use is limited because waste classification involves over 100 categories, which makes it difficult for non-experts to distinguish reliably the different typologies.

In Romania, respondents pointed to the experience of citizen consultation used to validate the Strategic Research Agenda, aligning research topics with community needs. This particular activity has enhanced the experience of CS platforms where researchers and citizens submit and collaborate on project ideas. This platform is seen as providing national visibility of CS and promotes citizen participation in research design and implementation. An NGO representative illustrated the experience of the creation of a civic initiative group to prevent deforestation and loss of urban park areas, and their experience in overcoming legal and organizational barriers by formalizing as an NGO, enabling fundraising, finding pro bono legal support, and stimulating community engagement. The initiative managed to establish collaborative actions with local authorities and to mobilize citizens and promote legal action for forest protection.

In the Spanish and international context, the mobilisation of citizens' rights derived from the Aarhus Convention have been mentioned to support CS processes to obtain evidence for administrative proceedings involving environmental issues. In the case of the ecological collapse of the Mar Menor, in southeastern Spain, many examples of CS have been reported. In these cases, members of the public have collected data on the presence or absence of flora and fauna species in the saltwater lagoon, irregularities related to intensive agricultural practices in prohibited areas, nitrate levels at the mouths of streams flowing into the Mar Menor, and levels of heavy metals in streams coming from the mining district of La Unión. Some of these initiatives have been supported by the NGO called "Pacto por el Mar Menor".²⁸

Cases in Sweden and Spain where CS data was used in legal and planning contexts, particularly concerning land use, were reported. In these instances, the reliability of the data was contested, but in situations where no other data exists, it fills critical gaps. In particular in Sweden a case was mentioned involving rare tree types and a proposed development. There was a court case where CS evidence helped prevent the development due to the discovery of these trees. The competent authority had not checked, but citizen scientists had – and it influenced the ruling.

A respondent from the UK noted that although their CS projects are not directly usable from a legal standpoint, many of them engage with policy development and align with EU goals. The person noted a grey area between policy guidance and judicial mandates, and the fact that overall, their work contributes to the shaping of policy-relevant science. Another case from the UK mentioned is the Sea Search project:²⁹ A diving-based CS project where volunteers are trained to record marine species. Some of the data collected has helped identify features off the North

²⁸ See <https://pactoporelmarmenor.blogspot.com/>.

²⁹ See <https://seasearch.co.za/>.

Norfolk coast that had not been officially recorded before. Other national initiatives cited in the UK context were the Big Butterfly Count³⁰ and Big Garden Birdwatch.³¹ While not directly compliance-focused, these initiatives provided environmental data in places where formal monitoring does not take place, which is seen as very valuable from a spatial planning perspective.

Still in the UK context, it was cited how data from initiatives like Riverfly,³² a structured programme where volunteers use biological indicators to monitor water quality, have been harnessed to support compliance. For Riverfly, volunteers have agreed trigger levels, so if certain types of invertebrates drop below expected levels, this can be used to indicate pollution and, in some cases, trigger investigations from the Environment Agency (EA). There have been instances where a Riverfly group reported a trigger breach, and the EA followed up with an inspection. In one case, action was taken, but the group then observed that the problem had returned, and their data showing this recurrence gave the EA the basis to reopen the case and take further enforcement action. So, in that sense, volunteers did not just identify pollution, but helped the authority to monitor post-enforcement compliance.

In Greece, the case of civic reporting of discharge of olive oil by-products (during olive oil production) was indicated. In addition, citizens reported the presence of wounded animals to the Forest Department or Natural History Museum of Crete. Lastly, several cases of CS contributions to Environmental Impact Assessments were reported by Greek respondents.

A respondent from an international research centre reported on the collaboration with the “Sensing for Justice” project³³ which focused on how citizens’ data can be legitimized as evidence in court proceedings in Europe and in the U.S. The U.S. was also mentioned by other respondents as offering good examples, particularly around water quality cases.

A professor of epidemiology from Italy shared with us cases of participatory epidemiology in Europe, such as the Cities Health project and the One Health Citizen Science project.³⁴ The methods developed in these projects have been replicated and applied in the Lucas project in Basilicata³⁵ supported by the regional government, focused on participatory epidemiology on the impact of oil emissions. The project started thanks to the impulse of a local prosecutor which gave the mandate to conduct research with royalties that were supposed to be used for this purpose but were never used. The expert also noted, however, that “the use of epidemiological data in litigation is more complex when this can create friction with citizens and associations.”

A legal expert from Belgium illustrated a noteworthy case:

“Flemish environmental law explicitly allows citizen participation in enforcement. Under Article 16.4.18 of the Flemish Decree Algemene Bepalingen Milieubeleid (DABM), natural persons and environmental NGOs are entitled to request the imposition of remedial sanctions when they have

³⁰ See <https://bigbutterflycount.butterfly-conservation.org/>.

³¹ See <https://www.rspb.org.uk/whats-happening/big-garden-birdwatch>.

³² See <https://www.riverflies.org/>.

³³ See <https://sensingforjustice.webnode.it/>.

³⁴ See <https://www.citieshealth.eu/> and <https://partecipa.poliste.com/assemblees/OHCS>.

³⁵ See <https://www.regione.basilicata.it/progetto-lucas-salute-e-ambiente/>.

knowledge of an environmental offence. While this mechanism does not extend to punitive sanctions, it does provide a channel for citizens to engage directly in enforcement processes. Between 2010 and April 2020, approximately 8% of all remedial sanctions imposed in Flanders were initiated through this legal provision by individuals or NGOs. This demonstrates a concrete example of citizen knowledge being translated into legal action. In practice, data generated by citizen scientists has also been used by public authorities. Dated photographs and local knowledge has been used alongside satellite imagery and mapping tools to support administrative enforcement. However, while data can be powerful, it is not always temporally precise or immune to manipulation (e.g., satellite data have very severe and strict protocols to ensure no tampering with the time of data collection). NGOs such as Natuurpunt and Vogelbescherming Vlaanderen (Bird Protection Flanders) have increasingly intervened as civil parties in criminal proceedings. Their participation is often backed by citizen-generated data. They assist courts in assessing ecological damage and in some cases, identifying patterns of repeat offending. For instance, in prosecutions involving illegal bird netting, the court has drawn upon NGO expertise to assess the severity and recurrence of the offence.”

As the interviews were open to cases also beyond Europe, below, we cite the words of a researcher and innovator³⁶ discussing an interesting case from Peru:

“Citizen science can and already does support environmental compliance by providing reliable, complementary evidence alongside official monitoring. In many cases, community members act as on-the-ground “sensors,” collecting data and observations that may otherwise be missed by authorities. Participatory environmental monitoring is a prime example: it involves local citizens in tracking environmental indicators (such as water quality, air pollution, or biodiversity) to ensure industries and projects adhere to regulations. This grassroots data collection can bolster decision making and accountability. For instance, in countries like Peru, communities are directly involved in monitoring the environmental impacts of mining and petroleum activities as part of formal compliance mechanisms. These citizen monitoring efforts serve as an independent verification of whether companies are meeting their environmental obligations. When local communities gather evidence (often with training and standard protocols), citizen science builds agency and creates an additional layer of oversight. In short, citizen-generated data can complement official data by filling gaps in coverage, providing higher resolution or real time information, and flagging potential non-compliance that warrants authorities’ attention. When properly validated and used, such evidence makes environmental enforcement more transparent and responsive to local concerns.

One notable experience comes from Peru, as mentioned before, where citizen science in the form of participatory environmental monitoring has been integrated into compliance processes. In the Peruvian context, Participatory Environmental Monitoring and Surveillance Committees (...) have a basis in law and operate in many mining regions. Mining and oil companies are encouraged (and in some cases required) to involve local community members in monitoring the environmental impact of their operations as part of the environmental management plans. (...) These participatory monitoring programs serve as a mechanism to verify industry compliance with environmental standards. In fact, Peru has some of the most specific legislation supporting such citizen

³⁶ Karen Soacha-Godoy, co-chair of RICAP (Iberoamerican Participatory Science Network) and researcher at EMBIMOS group involved in the RIECS-Concept European project (Towards a pan-European research infrastructure for excellent citizen science) at CSIC, Spain.

involvement in mining environmental oversight, recognizing that community participation can help prevent socio-environmental conflicts and improve transparency.

In 2024, this approach was strengthened by the creation of the first National Network of Environmental Monitoring Committees in Peru, which brought together local monitoring committees from eight different regions. The network formalizes the role of citizen monitors and aims to standardize their methods and advocate for legal recognition of the data they produce. These committees typically follow rigorous scientific and procedural methods to ensure their data is credible. (...) The participatory data have been used to inform joint decision-making between citizens, companies, and authorities at the local level, and have even been incorporated into community development plans as key environmental indicators.”³⁷

Category-related focuses

- *For civil society*

Missing competencies and resources reported, which limit the effective use of CS for environmental compliance. Include examples when cited.

Authorities must facilitate data collection and citizens must be given the time and intrinsic motivation.

The lack of information on processes and channels to have civic data heard by authorities was reported.

It was noted that citizen scientists may lack the necessary equipment/skills (for example for PFAS measurements) and thus support from specialised laboratories may be needed in certain cases.

There is the need for sensor calibration support, data analysis skills, and access to official measuring equipment. Citizen data credibility increases when combined with professional equipment and external statistical analysis, but this requires competencies.

Scientists from Greece stressed the need to educate the public to perceive the value of nature which is the first step to embrace a CS initiative.

Other respondents pointed to the weak institutional capacity to support engagement with non-traditional actors like citizen scientists; the absence of clear methodologies or resources to operationalize CS constructively; and the difficulty in developing forest-related projects or investments due to banking system unpredictability, which indirectly limits openness to experimental approaches like CS.

³⁷ See <https://www.grupodedialogo.org.pe/website/participacion-ciudadana-para-la-prevencion-de-conflictos-sociales-estudios-de-casos-comite-de-monitoreo-ambiental-participativo-juprog-orcopampa-y-mallay/> and <https://www.undp.org/es/peru/noticias/crean-la-primera-red-nacional-de-comites-de-monitoreo-y-vigilancia-ambiental-en-peru>.

Other missing competencies reported included the lack of legal expertise, public awareness, and access to enforcement mechanisms; as well as financial constraints and property rights disputes which often override environmental considerations.

A recurring trend in Greece and Romania is the limited public education on the matters due to the underrepresentation of environmental issues by the mass media; a lack of informative publications; fragmented presence of environmental topics in schools' curricula and outdated material regarding environmental issues in school textbooks; lack of access to information on a micro-scale (about local issues) for citizens.

A respondent from a British NGO put this answer in very clear terms which we report as a citation:

"Several competencies and resources are missing:

- Policy engagement: In many regions, authorities are unwilling to listen or act on citizen-generated data. In the UK, for example, the Environment Agency is not receptive, possibly due to concerns about public backlash or lack of resources. In contrast, in Africa, authorities engage enthusiastically because of the cost-effectiveness of citizen science.
- Capacity: Even when data is collected, agencies often lack the financial or human resources to analyse and act on it. The UK's monitoring has recently been cut by over 30%, leaving significant data gaps that citizen science could help fill—if there were systems to absorb and use the data.
- Bias in data collection: Volunteers often seek to confirm problems rather than monitor baseline conditions. This results in data that's skewed toward "interesting" or problematic areas, while "boring" but important areas may be underrepresented.
- Stakeholder trust and conflict: In agriculture, there's often mistrust between farmers and citizen science initiatives, especially when water quality is being monitored. Farmers may fear they're being unfairly targeted, making collaboration difficult.
- Inclusivity: Citizen science tends to attract middle-class retirees in well-off areas. Engaging underrepresented or deprived communities remains a challenge, partly because the benefits of environmental monitoring are not always obvious or urgent for them."

A spokesperson from a citizen science initiative from Italy noted that there is a need for training to access and read geospatial data. Their initiative had to purchase images for detecting methane emissions from industrial operations. As these images are not open source, they are purchased for a period of time, such costs are burdensome for small-scale initiatives. A professor of Earth Observations (EO) also from Italy confirmed this, noting also that civic monitoring could start from Sentinel2-5P, which offers free data,³⁸ compared to other, costly, sources such as Planet Scope.³⁹ The person also noted that, in the context of Italy, citizens should ask to the Italian Space Agency (not the European Space Agency) for images that they could use in their monitoring, stressing the authorities' duty to cooperate. EO can be used for example to monitor waste disposal and the safety of a landfill, also creating an historical memory of a site. In addition, the person

³⁸ See <https://sentinels.copernicus.eu/web/success-stories/-/copernicus-sentinel-2-data-help-monitor-methane-point-source-emissions>.

³⁹ See <https://docs.sentinel-hub.com/api/latest/data/planet/planet-scope/>.

from the Italian CS initiative noted that in their particular context the need for support with conducting participatory epidemiological studies for assessing the impacts of extractive operations on people's health would be very much needed.

Interestingly, a member of the Italian Citizen Science Association and experienced with CS projects from Italy noted, pointing to a barrier but also a possible solution:

"There is a lack of standardisation. Citizen science originates from small groups that decide to use a methodology that is not always extensively studied before being implemented. There is the problem of scientific validation of data in order to be recognised correctly. The data should be used by all countries (a common database where data is collated). The proposal is that there should be scientifically validated interoperable methods and the construction of at least a national platform that can be shared at European level. In this sense, the need for scientific experts is fundamental in order to seek the validity of the data by the authorities. (...) The European Citizen Science Association - ECSA has written 10 principles of CS to make what is being done more valid.⁴⁰"

An interviewed representative of Greenpeace International noted:

"Missing competencies and resources vary from case to case. In my specialist area of air quality, a major limiting factor is the availability of reference grade air quality monitoring instrumentation. Low-cost air quality sensors are readily affordable to citizen groups, but best use of these devices requires that they are carefully compared to data from reference instruments ('co-location studies'). In many countries reference grade instrumentation is not available, and in further countries where competent organisations operate reference grade instruments they are not willing to cooperate with citizens who wish to undertake co-location studies. On this point, it is worth mentioning recent efforts by the US EPA and UK Defra who have produced guidance for the use of citizen grade air quality monitors."

Barriers reported in using CS as evidence in court and as an alert to enforcement authorities such as the police. Include examples when cited.

Also, the lack of motivation among citizens regarding CS applications for compliance assurance was mentioned. A concern was associated with the fact that citizens may be negligent or deliberately falsify data, for augmenting environmental problems. Financial limitations and time limitations of civil society were often cited. The fact that the public does not have easy access to all data held by authorities was also referred to. Other barriers reported include: the lack of auditability as data needs to be trackable from source to courtroom; no versioning mechanisms: without version control, data integrity cannot be assured; loss of metadata: many systems strip essential metadata (e.g., time, GPS), making evidence weaker; the risk of falsification or manipulation, especially without strong integrity mechanisms (e.g., hashing, golden copies). Using golden copies and metadata-preserving apps for photos and implementing hashing from the start of data collection were seen as coping strategies. Other barriers reported included the limited trust in citizen-collected data being used in legal or enforcement settings, and the consequence that data would be immediately challenged or dismissed due to lack of objectivity and credibility issues. Also fears that citizen alerts could lead to stigmatization or overexposure

⁴⁰ <https://www.ecsa.ngo/10-principles/>

in the media and among enforcement bodies without due process were reported. In certain countries, such as Romania, the low awareness among citizens and even authorities regarding how to address environmental violations (e.g., forest code enforcement on private property) was reported as a barrier. In Greece, a ground for exclusion for the collected data was the fact that such data included personal data of other people and the fear that people have to be identified in the data reported, limiting its usage.

A respondent from a British NGO put this answer in very clear terms which we report as a citation:

“Several barriers exist:

- Data validity and legal acceptance: There is still scepticism about the reliability of citizen science data in legal contexts. In early cases (e.g., Sweden), the data was contested in court. While it was ultimately accepted, it required significant legal effort. There's a lingering bias that official data is more credible, even when citizen data is well-documented.
- Systematic integration: Authorities often lack mechanisms to systematically integrate citizen alerts into enforcement workflows. This results in citizen reports being ignored or deprioritized.
- Political resistance: There's often reluctance to accept citizen science as legal evidence due to political considerations, especially when it may expose underperformance by public agencies. For instance, UK environmental authorities might avoid acknowledging such data to prevent further negative press.
- Perceived risk of misuse: Concerns exist that citizen scientists may have an agenda, such as targeting polluters or specific stakeholders. This can reduce trust in the neutrality of the data, particularly in court or enforcement settings.”

- *For representatives of an authority*

Conditions and situations under which respondents would rely on CS for supporting environmental compliance. Include examples when cited.

Respondents pointed to the fact that data must be validated by a scientific expert or sectorial organization like the IUCN. In order for CS to be used effectively for environmental compliance, there must be a demand for data from the authorities and a willingness from citizens to collect it. Appropriate timing in the research or compliance process was also reported as essential to ensure quality contributions.

An authority's representative encouraged forms of CS that favour collaborative formats that emphasize listening and learning over confrontation or monitoring. The person also invited values processes where citizens are involved through dialogue and mutual understanding, rather than in adversarial roles. Accepted formats included CS projects, where shared responsibility and mutual respect guided cooperation. Rejected formats are instead those driven by external pressure, public shaming, or unilateral action from NGOs or media. Citizen engagement through contributing data was seen as valuable when supported by training and tools (e.g., phone apps, explanatory kits).

Authorities' representatives often stressed the need for standardised methods, spatial accuracy, data verification, and health and safety trainings for the volunteers. A representative of an international research centre noted that citizens themselves can have specialized experience that adds significant value in quality control of data.

A Belgian representative of a local authority stressed the importance to have an independent intermediary who has a certain connection to the government to open dialogue, but also trustworthy enough, and credible enough to go over and facilitate the discussions. These can be knowledge institutions such as universities which can “do sociological or judicial “translations” (acting as facilitators of discussion between the authorities and citizens).”

A representative of a British environmental authority (EA) stressed the need to bridge the gap between the formal regulatory framework of the EA and the work of volunteers who are collecting data on the ground — often to a high standard, but outside of official systems, to ensure that non-regulatory data can meaningfully inform EA decisions on a local scale, especially in the water sector. A relevant quote from the EA person is reported below:

“There are several important conditions for that data to be reliably used:

- Simplicity of reporting: The process for submitting data has to be easy. We're working on improving our reporting, in which we encourage users to upload photographs and as much supporting information as possible. This would make it easier for EA staff to quickly assess incidents.
- Clarity about quality and accuracy: Officers need to know if the data is robust. It's really helpful when the confidence level or validation process of the citizen science project is clearly documented — like it is with Riverfly, where the methods are standardised.
- Trust and transparency: Internally, we need to build greater trust in external data. At the same time, we need to provide citizen scientists with more feedback about what happens to their data. A major complaint is that people report incidents but hear nothing back — and so they assume their efforts were ignored.
- Realistic expectations: We do have to manage expectations. For example, we don't usually respond to incidents below Category 1 and 2 (respectively, the most significant, nation-wide, and significant but less critical, regional scale, environmental pollution incidents), due to limited resources. That's frustrating for the public, but it's the current policy.
- Use as intelligence, not legal evidence: I don't think citizen science data should generally be used as the primary legal evidence in court. The burden placed on a volunteer would be too high, and the legal process can be adversarial. Instead, we should use it to trigger investigations, which are then backed up with official EA-collected evidence.”

Barriers limiting institution's ability and/or willingness to rely on citizen science for supporting environmental compliance. Include examples when cited.

Citizen-generated data is often perceived as less accurate and less trustworthy. Enforcement acceptance depends on validation, and courts may require external expert analysis before acting on citizen data, and this may discourage institutional uptake of the data. The issue of understaffing

of nature protection agencies was/has been discussed. Citing a respondent “there is no organisation (top to bottom), no backup, no detailed plan, no training, no financial support (most good community-led organizations in the UK receive no financial support, they buy their equipment themselves)”. Lack of funding for awareness-raising and communication; perceived double standards and activism from environmental NGOs.; economic and bureaucratic burdens associated with engagement processes were reported as factors contributing to a general reluctance to engage in monitoring based on CS for enforcement. Other barriers seen by authorities include:

- limited citizen skills in technical domains;
- ethical issues including GDPR compliance;
- mutual lack of trust:
- Experts' hesitation to accept non-expert data,
- Citizens' uncertainty about their contribution's value;
- continuity issues:
- engagement often driven by personal interest, making it difficult to sustain;
- misaligned expectations:
- Citizens' need for clarity on how their data will be used and what impact it can have. A telling quote from a respondent says “The key thing is CS needs to be recognised as part of the system. This is not the case now.”

A respondent from an environmental authority in Belgium added the following important points:

- the challenge to manage peoples' expectations;
- the difficulties in finding independent intermediaries to do the translation between the authorities and the citizens;
- the challenge to establish a trustworthy relationship between the citizens and the authorities;
- and, finally, the lack of agreed standards applicable to monitoring certain parameters (for example PFAS levels in blood), as even between governments standards can differ.

Another barrier to a larger uptake of CS data by authorities is the varying relation with authorities across European countries, which would be much more structural in countries like the UK whereas in other countries like Italy it is very difficult for citizen scientists to get a contact point to enter into dialogue with agencies. The interviewed person also pointed to agencies much more open to sharing raw data with citizens, such as the Dutch Institute for Health and the Environment (RIVM) compared to e.g., the Italian Regional Protection Authority (ARPA).

- *For legal experts*

Reported procedural and substantive standards applicable to CS if used to provide evidence in court. Include reference to admissible court evidence in criminal proceedings in the specific countries when reported.

Legal professionals agree on the need for data quality assurance and institutional acceptance – especially at the court and lawyers' levels. There was a wider recognition of the potential of CS to

contribute meaningfully to environmental compliance, particularly if multiple independent observations are used for corroboration. The importance to focus on admissibility and reliability in court of data has been stressed and depends on factors such as collection method; intent of the collectors; auditability and metadata preservation. Legal experts interviewed reiterated that CS, if used as evidence in judicial proceedings, must comply with the procedural and substantive standards applicable to evidence (criminal, civil, or administrative). A law professor noted “the most critical distinction is not necessarily between the different types of courts (criminal, civil, administrative), but rather between punitive and remedial sanctions. In the context of punitive sanctions, the presumption of innocence applies, so data integrity and transparency are important.” The principle of free evaluation of evidence was also stressed as critical in both criminal and administrative contexts. The professor stressed:

“In administrative enforcement settings, environmental inspectors are taught to include scale references in photographs, for instance, when photographing a suspected illegal waste dump, inspectors are advised to include objects of known size (e.g., a glove or a person) for scale. These same principles apply to citizen science. Courts give particular weight to evidence that includes precise time and location data. Data not geotagged at the point of observation may raise questions. Finally, specialised prosecutors and judges are far more likely to understand the ecological significance of data, e.g. through formal training programmes.”

A lawyer from Italy focusing on civil and administrative proceedings noted that:

“Civic evidence can be used directly in the dispute, subject to cross-examination, and can be considered as sui generis partisan evidence, which could represent an important shift from a technocratic approach to a civic-inclusive approach (...). It may be new at the political level, but not necessarily in terms of legal technicalities. Scientific validation of the civic evidence can help through. And the political and legal dimensions of civic evidence are and must remain different: otherwise, risk that the judicial process may be considered disrupted by political factors”.

The lawyer also stressed that civic evidence, if validated by scientific experts, e.g. the Italian National Research Council, can become ‘well-known facts’ which are no longer contestable and then used by the various parties. It is important to keep the factual elements separated from the scientific elaboration. However, the lawyer noted that even ‘classic’ scientific data can be contested as science evolves, or in any case there is reasonable doubt as to whether those thresholds are harmful or whether those sources of pollution are the prevailing ones.

A judge and prosecutor from Italy agreed with these positions expressed by the lawyer cited, and stressed that “in the Italian code, the atypical nature of evidence is the rule; CS evidence can thus be used as testimonial evidence or as preliminary evidence for further investigation.”

Overall, the civic data was indicated as to be used in conjunction with expert data and testimony. Below we report the quote of an environmental lawyer from Spain on the matter:

“In my opinion, in legal cases, it is very important that the data, although collected by citizens, be interpreted by private or public experts who have access to that data. Private experts can represent an economic barrier to access to justice due to the cost of their reports, but solutions can be sought through NGOs by incorporating expert analysis into specific projects. Sample collection in the

presence of a Notary could be an option for citizen science, although I don't believe Notaries are prepared to store samples. However, they could oversee the handover and return of the samples to and from laboratories, which are capable of guaranteeing proper custody. In the case of public experts, citizen science would be of limited use, as the data must be collected in a way that guarantees the sampling process and chain of custody are followed closely —something only a public official, such as a Civil Guard (SEPRONA) officer or an environmental inspector, can ensure."

In relation to criminal investigations in Italy, the lawyer informed us that criminal proceedings may be initiated following a civic complain and the civic party as injured party: in this case, the same civic evidence given to the public prosecutor's office may or may not necessarily be used in the litigation. In any case, the evidence will be used in conjunction with other evidence and perhaps be reinterpreted by the public prosecutor.

Reported procedural and substantive law requirements which could pose obstacles to the effective use of CS for environmental compliance.

An environmental lawyer summarized this point with a simple sentence: "With respect to admissibility, I think you will always have the same rules as other data used for evidence, as we said, or you will always need recognized experts to evaluate them." An Italian judge and prosecutor noted that "the ordinary rules for evidence would apply to CS, and thus there are no barriers other than those of the reliability of the evidence."

Other respondents reported the need to ensure early-stage integrity: legal standards must be considered from the moment of data collection, not retrofitted later. The correctness of the data gathering procedure (e.g., number of samples, sequence, storage) was often cited as crucial. Certification mechanisms by environmental agencies are also seen as useful, but reliance on certified laboratories could be an alternative. However, the issue of how the data was collected remains open, according to several interviewed legal experts. A strategy to tackle this barrier could be having scientists acting as witnesses or acting as *amicus curiae*, indicating their favour for the civic evidence presented in an amicus brief (which is a legal document submitted to a court by an individual or group that offers information, expertise, or arguments to assist the court in making a decision in support of one or the other party to the case).

For a legal expert and researcher in the Netherlands, Dutch courts would not accept CS data. However, in this person's opinion, civic data can be used to support early enforcement as it can lower compliance costs and increased granularity of data.

In Romania, an NGO representative reported of an unfavourable legal framework for green spaces and absence of public green space registers; property rights conflicts and delayed compensation for environmental protection measures; ethical challenges deriving from prioritizing economic value and profit over ecosystem value.

A Spanish expert stressed the importance of authenticity of the samples and the chain of custody during their transport to and from the laboratory, as well as the presence of an expert witness to present the results and conclusions.

A lawyer from Belgium noted that the authorities are a bit suspicious of the motives of NGOs and citizens, and, with respect to pollution, citizens are suspicious of the authorities, because they did not monitor the pollution throughout the years in the first place.

Comments on the legal expertise needed for the effective use of CS for environmental compliance.

More legal professionals need to be specialized in environmental law, administrative law and procedural law. Judicial authorities need to be trained to use the testimonies of civil society. Researchers on CS need to engage environmental prosecutors in this type of studies. The issue of CS initiatives needing to get legal expertise was reiterated, including:

“a) Legal advisors familiar with enforcement, b) Specialised prosecutors and judges. Without specialization, critical data may be dismissed, especially in cases involving cumulative or “confetti-criminality” (where individual infractions seem minor but their repeated occurrence signifies serious harm), c) Training and awareness at the environmental inspection chain. In Flanders, for example, inspectors are trained at different levels of specialisation—from basic local compliance checks to fully specialised 24/7 environmental inspections.”

A law professor noted:

“In practice, it is unrealistic to expect individual citizens to bring environmental cases before the courts on their own. While it does happen, they are often burdened by work, family, and financial obligations. Many take on cases that should have been handled by public authorities years earlier. To support such efforts, citizens often rely on collective fundraising mechanisms, such as crowdfunding. Legal costs remain substantial. Environmental lawyers who take on such cases frequently do so at greatly reduced fees—sometimes bordering on pro bono, but this is not a sustainable model in the long term. This is why environmental NGOs are absolutely essential.”

A civil lawyer added that it could be useful to establish protocols between CS associations and prosecutors to ensure that there is mutual trust.

A judge (who also worked as prosecutor) stressed the need of having technical and legal assistance from legal associations or dedicated NGOs to produce this civic evidence and ensuring that citizens produce data analyses that are actually helpful to judges in coordinating various sources of evidence. Also, the school for the judges should prepare them to handle CS evidence, in the judge’s view. The judge also believed that CS initiatives must be supported by technical, scientific and economic expertise in addition to legal expertise. They affirmed “If you don’t know how the judicial system works, you’ve lost the case! Understanding who to deal with, establishing relationships is key.”

Shared actual cases in which CS has been used in judicial settings.

The lawyers and legal experts interviewed rarely pointed to actual cases of CS being used in court cases. Among the few that did so, a lawyer noted that they used some kind of CS in court cases, going to court cases “with citizens’ blood tests, tests of blood that are not taken by officials (to measure pollution in citizens’ blood)”, but the person faced scepticism from the authorities. The person noted “the authorities should make use of organized citizens. And for me, organized citizens are a kind of CS because they perform work that is not performed by the authority”. An

environmental authority from Belgium commented that “there was a big blood investigation, 17,000 people had their blood taken to see PFAS levels in their blood. And by combining those 17,000 results, it could be identified where the most affected areas were located, what other parameters were involved, and according to that, the local policy can also change.”

A judge and prosecutor from Italy noted that in several cases that they handled (spanning from pollution from a refinery to pollution of water sources) the reports came from private individuals, but these reports cannot be considered scientific evidence, but rather ‘civic complaints’ or ‘physical evidence’. We discussed the difference between the (to our knowledge only) Italian case where the participants from a CS initiative have been invited to testify as witnesses based on their CS monitoring to support environmental compliance in a court case for environmental disaster for mismanagement of a water purifying plant in Campania.⁴¹

A person from the legal team of Greenpeace International shared with us that the cases they handle mostly related to two types of cases: i) those that combine CS data with professional data to increase coverage, and have been used in judicial settings; ii) those that force the activation of official monitoring, demonstrating the lack of data with CS. The person shared a case from France,⁴² where an air quality CS study close to a school was developed by parents and divided into two parts. The first part on data validation process: the data from CS and the official monitoring system were compared (the CS sensors were located close to the official ones). Secondly, the CS sensors were validated due to no difference being detected between them and the official sensors. The CS sensors were located in areas not covered by official sensors, such as close to a school centre.

There was an attempt to reject the CS data, but in the end, it was accepted. The person interviewed, noted that it is currently a common process developed by professionals that uses mixed data sources to cover geographical or parameter-based areas. Interestingly, the person shared also a case of CS in Iraq to discuss of another common use of CS data, which is to collect a large amount of data and information, including low-quality data, to provide a snapshot of the situation and evidence of the lack of official monitoring. This has been done in an area designated for an air pollution study in Iraq, close to an oil and gas field. The legal department used the information to alert the government to the lack of monitoring, considering it to be their legal duty to monitor the area. The CS data were indirectly used to legally foster the activation of monitoring.

- *For innovators in the tech sector*

Reported technological barriers that limit the possibility to use CS for environmental compliance. Include examples when cited.

Low-cost sensors can be influenced by humidity and temperature, requiring calibration models and validation against professional stations. High effort is required to train and engage citizen

⁴¹ See <https://cleansealife.it/dischetti-2/> and <https://cleansealife.it/2020/12/16/clean-sea-life-e-il-primo-processo-italiano-sul-mare-di-plastica/>.

⁴² See <https://www.greenpeace.to/greenpeace/?p=4667>.

scientists to ensure data quality (online training sessions, community-building events). Limited coverage by volunteers and the need for high-quality, validated observations (especially for difficult-to-detect species) remain challenges. Usability of tools (user-friendly, engaging) to sustain participation should be considered, as participation is not always guaranteed. Also, the overarching issue of limited financial resources for upscaling CS initiatives was cited.

A major barrier was identified in the general crowdsourcing methodology, as research project managers have to relinquish a certain degree of control over the data. This leads to uncertainties in the data, which can vary depending on the project and may result in the data not being accepted by authorities. Although data quality can be an issue, the person emphasized that even with poor data quality, positive side effects such as public participation and communication about environmental compliance can emerge.

Below, we cite an illustrative passage from an interview with a researcher and innovator:⁴³

“Despite its potential, there are several technological barriers that limit the use of citizen science for compliance purposes. The basic one, the digital divide remains a significant challenge. Not all communities have equal access to the internet, especially in remote or low-income regions, which means many willing citizen scientists lack the tools to contribute. Second, data governance and privacy concerns present challenges. Environmental compliance often deals with sensitive data, for instance, evidence of pollution or legal violations, which can implicate powerful interests. Citizen science projects gathering such data may face risks (e.g. harassment of volunteers or legal challenges), so they require robust protocols for data privacy, security, and participant anonymity. Developing technology platforms that enforce these protocols (for example, secure databases, anonymized data collection apps, or encrypted communication channels) is complex. Such tailored technological solutions are often beyond the capacity of grassroots groups to build or maintain without support.

This leads to a third barrier: lack of sustainable infrastructure and funding for citizen science technology. Many citizen science efforts rely on short-term project funding or volunteer labor, and they use free or low-cost tools. Ensuring long-term maintenance of data platforms, regular updates for software (to remain compatible with evolving standards or to patch security issues), and hosting large datasets require resources that citizen science initiatives typically struggle to secure. If a citizen science platform goes offline or data storage is not maintained due to funding cuts, any compliance evidence collected could be lost or rendered unusable over time. Another barrier is the challenge of translating ethical and quality standards into shared practices (..).”

If mentioned, any consideration related to the data readiness level needed for CS to support environmental compliance.

CS sensors can provide continuous data coverage and identify trends, but still require official confirmation for legal use, if they are properly calibrated. Ensuring admissible data quality remains a constant. Observations by citizens are often geographically limited and lack

⁴³ Karen Soacha-Godoy, co-chair of RICAP (Iberoamerican Participatory Science Network) and researcher at EMBIMOS group involved in the RIECS-Concept European project (Towards a pan-European research infrastructure for excellent citizen science) at CSIC, Spain.

redundancy, making it hard to guarantee reliability. Converting multimedia observations (images, sounds) into legally usable evidence is complex and requires robust validation procedures. The need of drawing from existing protocols to guide best practices for evidence quality was stressed. Involving legal experts in the development of DRL scales to ensure courtroom applicability was indicated as a strategy. Recognizing that DRL must account for context, including the intended legal use, reliability requirements, and corroboration needs was suggested as well.

It was also noted that the data readiness level for the acceptance of CS data by authorities depends heavily on the domain, the authority, and even the individual who decides on the use of this data. CS data often offers a higher spatial resolution than professionally collected data, which can represent a gain in information despite potentially lower data quality.

An innovator pointed to the need for collaboration between CS and the private sector noting that “CS models should be audited by competent auditors of the industry in order for them to be able to bring things to court” and suggested that citizen scientists should cooperate more with the industry.

Another innovator⁴⁴ interviewed suggested that there cannot be a single universal DRL for environmental compliance that all CS data must achieve. The necessary level of data readiness depends on the nature of the CS project and the context in which the data will be used. In other words, different projects may need to achieve different levels of data maturity to be considered credible for compliance purposes. For example, in large contributory projects, it is enough that these datasets achieve a mid-tier readiness (e.g. Level B in some DRL frameworks) as they are sufficiently validated through statistical methods and volume to identify compliance issues like a pollution trend, even if not every single entry is verified in the way an official lab sample would be. On the other hand, co-created or collaborative CS projects (for instance, where community members and scientists design and execute a monitoring plan together) can yield highly reliable, contextualized data that may meet the strictest standards. In these initiatives, protocols are often co-developed to align closely with official methods, and the data collection is more targeted. The data from such a project might achieve the highest readiness (comparable to Level A) because it can be directly compared to official data in accuracy and detail.

It was also underlined that some citizen datasets might be immediately admissible as evidence, while others might be better for preliminary screening or supplementary information. Therefore, CS initiatives should determine the required DRL based on the project’s design and the intended use of the data. High stakes enforcement actions (e.g. prosecuting a polluter) will demand citizen data to be of the highest quality and documentation level, whereas routine monitoring or community awareness efforts might accept lower readiness data that is nonetheless indicative.

A relevant quote on the relevance of DRLs ending with a practical suggestion is reported below:

“DRLs can be a tool to get authorities to read CS data but the first step is recognition, not necessarily legal use but almost, as standard practice at national level, a recognition that there is cooperation

⁴⁴ Ibid.

between CS and authorities, including at a technological level. Governments should provide guidance on DRLs and strengthen this relationship from the ground up, perhaps by including CS in directives and regulations. An opportunity for this could be the Nature Restoration Law of 2024”.

Considerations on how to ensure that CS data becomes legible and interoperable with official data from enforcement authorities to be used for environmental compliance.

Respondents highlight the need for data sharing protocols and cooperation with official agencies to improve credibility and facilitate integration into enforcement processes.

AI applications can boost CS for environmental monitoring and compliance assurance. Citizen scientists can label complex images, providing ground truth for AI models that automate monitoring tasks, detect illegal waste disposal, ghost gear, or ecosystem changes indicating illegal fishing.

Data generated by citizens is valuable for monitoring and AI training, providing initial indications of environmental issues, but not replacing official evidence for compliance and enforcement.

Tools must ensure that CS data is legible and compatible with official monitoring systems, which requires careful design and additional data validation steps.

Professional and low-cost sensors can be placed less than a few meters away from each other for improving the calibration and validation even further, in cooperation with authorities.

Auditability systems are needed to document each step of the data lifecycle. Interoperability through shared standards including version control and metadata preservation is key. Systems that allow contextual linking of data types, e.g., pollution and biodiversity data from the same area, even if initially disparate is key. Avoiding data silos and instead designing tools for proactive and reactive data use (e.g., alerts vs. post-hoc evidence) was stressed as important.

An interviewed researcher and innovator noted that ensuring that CS data is legible (understandable, credible) and interoperable with official datasets requires “a holistic strategy” involving standardization, validation, and institutional recognition. Below we cite abstracts from her statements:⁴⁵

“On the technical side, one key step is to adopt common data standards and formats so that data collected by citizens can be easily merged or compared with government data. For example, in biodiversity monitoring, citizen observations are often shared using standardized schemas (like Darwin Core) which allow integration into national and global databases. For instance, the Global Biodiversity Information Facility (GBIF), which aggregates data from many sources including citizen science projects, in fact, nearly half of all species occurrence records in GBIF come from datasets with significant volunteer contributions. This is possible because those projects publish data with the required metadata and quality checks.

⁴⁵ Karen Soacha-Godoy, co-chair of RICAP (Iberoamerican Participatory Science Network) and researcher at EMBIMOS group involved in the RIECS-Concept European project (Towards a pan-European research infrastructure for excellent citizen science) at CSIC, Spain.

Similarly, for environmental compliance data (...), developing open data catalogues or portals where citizen science datasets can be uploaded in machine readable, standard format will make it easier for enforcement authorities to discover and use them. Although these areas remain challenging, because of the diversity of standards and protocols used for citizen science initiatives and the lack of an infrastructures such as GBIF in the water, air quality or climate change domains. These datasets should include rich metadata describing how and where the data was collected, by whom, using what methods, and an assessment of its quality or uncertainty. Including a DRL indicator in the metadata could be extremely helpful. It would signal to officials the degree of validation or processing the citizen data has undergone (...).

On the institutional side, it is crucial to achieve formal recognition of citizen science data by regulatory authorities and statistical agencies. This might involve developing new policies or guidelines that outline how citizen science data can be used in enforcement. Notably, the international community is moving in this direction. The United Nations Statistical Commission in 2023 called for integration of citizen generated data into official statistics, resulting in what is now called the “Copenhagen Framework on Citizen Data,” which provides a conceptual foundation for incorporating citizen science data into national data systems. Following this, some countries are taking action: for instance, Colombia’s National Statistics Department (DANE) has been co-developing a data maturity model for citizen data aligned with this framework. Such efforts produce protocols and assessment tools that can help official agencies systematically evaluate citizen science contributions (e.g., checking if the data meets certain quality criteria) and then incorporate them into their databases or reports. Another important aspect is legal frameworks that mandate or facilitate the use of citizen data. Environmental authorities may hesitate to use external data unless there is a clear mandate or protection for doing so. The Escazú Agreement in Latin America and the Caribbean is a pioneering treaty that, among other provisions, obliges its signatory countries to improve access to environmental information and to promote public participation in environmental decision making. This kind of high-level legal commitment creates a supportive environment for citizen science data, governments are compelled to listen to and include citizen generated evidence as part of upholding environmental rights. Under such frameworks, an environmental agency might be more empowered to, say, accept data from a community air quality network as part of its compliance checks, or to create channels for the public to submit evidence of environmental harm. However, simply having data available and legal encouragement is not enough; the data must also be perceived as valid and actionable by authorities. This is where establishing credibility and trust is vital. Joint training programs or pilot projects can help (...). Government agencies could establish clear procedures for reviewing and approving citizen data, analogous to how third party environmental audits are handled. They could also assign liaisons or create dedicated units to interface with citizen science initiatives, ensuring that submitted data is checked and fed into compliance actions when appropriate. Finally, interoperability is a two-way street. On one hand, citizen science projects should strive to make their data as user friendly for authorities as possible (through standardization, documentation, and quality assurance). On the other hand, authorities and enforcement bodies must be willing to open up their information systems and workflows to outside inputs. This might involve updating data management systems to ingest external data, training staff to understand citizen science methods, and fostering an organizational culture that values public contributions. It may also require providing feedback to citizen scientists, for instance, if a community submits evidence of a violation, the agency should inform them of how that data was used (or why it could not be used) in order to build trust and

improve future efforts. With both sides working in concert, citizen science data can become truly interoperable with official data: technically integrated, yes, but also institutionally and culturally integrated into the environmental compliance process.”

Cross-country and cross-category main differences

When comparing the perspectives emerging from Spain, Belgium, the Netherlands, Austria, Romania and Italy, the interviews reveal significant differences not only between countries but also between categories of respondents. In general, while Western European respondents tend to see CS as a credible, if not complementary, source of evidence for environmental compliance, the degree of institutional trust and professional acceptance varied considerably.

In Spain, most interviewees, particularly those from civil society and the legal community, described CS as a driver of civic mobilisation and a channel for exercising environmental rights under the Aarhus Convention. The cases surrounding the Mar Menor lagoon exemplify this view: citizen initiatives, often supported by NGOs such as Pacto por el Mar Menor, collected and publicised data on pollution and biodiversity loss to pressure local and regional authorities. Spanish lawyers interviewed, acknowledged the potential of such data in administrative proceedings, provided that it is validated or accompanied by expert reports. One legal expert even suggested procedural innovations, such as notarial oversight of sample collection, to enhance evidentiary legitimacy. This reflects a generally pragmatic legal culture open to civic contributions but attentive to procedural rigor. By contrast, technical experts and environmental authorities in Spain were less focused on compliance enforcement and more on awareness-raising.

In Belgium, and particularly in Flanders, the institutional framework appears more advanced. Legal experts and public officials highlighted that Flemish environmental law explicitly recognises citizen participation in enforcement. Respondents from the legal community pointed to Article 16.4.18 of the Flemish Environmental Policy Decree (DABM), which allows individuals and NGOs to request remedial sanctions in response to environmental offences. For this group, CS data can underpin legal action, particularly when supported by NGOs such as Natuurpunt and Vogelbescherming Vlaanderen, which act as civil parties in criminal proceedings. Representatives of authorities confirmed that such citizen-generated evidence when corroborated by photographic documentation or mapping tools – has been used to support administrative investigations. However, divergent views emerged among legal professionals and innovators: some considered CS an effective tool for biodiversity-related crimes, while others warned that it may create just information overload and confusion on responsibilities.

The Dutch context, by contrast, was described by respondents from both technical and civil society backgrounds as highly collaborative and technologically advanced. Innovators and researchers pointed to cases where low-cost sensor data, once validated through official equipment, generated credible and actionable evidence – sometimes leading to judicial proceedings. Authorities such as the National Institute for Public Health and the Environment (RIVM) were cited as examples of openness to civic data sharing. Dutch respondents across categories highlighted the importance of methodological standardisation and the co-production of knowledge between institutions and

citizens. The civil society perspective in the Netherlands was more optimistic than elsewhere, seeing CS as a tool that strengthens transparency and mutual trust rather than one limited to advocacy. Legal professionals, while acknowledging the role of CS in triggering enforcement, remained cautious about its admissibility as formal evidence.

In Austria, respondents described sharply different contexts of civic participation. Austrian interviewees, particularly from environmental NGOs and authorities, referred to “Citizen Initiatives” that have successfully prevented construction projects harmful to biodiversity. These initiatives rely on citizen-generated evidence and illustrate how civic monitoring, when framed within participatory legal channels, can directly influence decision-making. Civil society representatives tended to see CS as a constructive and preventive practice, while authorities acknowledged its usefulness for awareness and early detection. In contrast, Romanian respondents presented a more polarised picture. Representatives of the forestry sector dismissed CS as unreliable and politically disruptive, citing distrust in environmental NGOs and fears of data manipulation. Conversely, civil society actors insisted that structured and validated citizen monitoring is essential for raising awareness.

The Italian experience sits somewhere between these two poles. Interviews with judges, lawyers, scientists, and activists suggested that CS is increasingly recognised as a preventive and collaborative tool, capable of exerting pressure on institutions and prompting investigations. A judge and prosecutor noted that civic monitoring can play a preventive role and, when trusted by police and prosecutors, may lead to independent inquiries. Legal experts stressed that Italian procedural law allows for “atypical” forms of evidence, meaning that civic data can be introduced as testimonial or preliminary evidence if scientifically validated, for instance by the National Research Council (CNR). However, all categories of respondents highlighted barriers: the lack of standardised methods, interoperability, and institutional channels for dialogue between citizen scientists and environmental authorities such as the ARPA system. Technical experts mentioned high costs and restricted access to geospatial and satellite data.

Across these eight countries, the comparison reveals a clear gradient of institutional openness and civic trust. The Netherlands and Belgium demonstrate high levels of procedural maturity, where citizen data is valued and sometimes integrated into enforcement. Spain and Italy show growing engagement and experimentation, where civic evidence serves as a catalyst for prevention and public accountability rather than formal litigation. Austria and Romania, while geographically close, represent opposite ends of the spectrum: in Austria, citizen initiatives have achieved institutional recognition, whereas in Romania, low trust and sectoral conflicts continue to constrain collaboration. Overall, the interviews suggest that the effectiveness of CS as a compliance instrument depends less on technological capacity than on the legal culture, institutional receptiveness, and degree of cooperation between citizens, experts, and authorities.

capacity building programmes must move beyond basic technical training. In this context, the work carried by the ENFORCE project must explicitly target the underlying institutional bias and distrust identified in the T2.3 interviews by demonstrating how the EC-DRL framework ensures data reliability and neutrality, thereby creating institutional capacity for civic evidence.

Any other relevant information added by the respondents

In certain cases, political parties – in particular the Green Party – cooperated with citizen scientists to launch initiatives that were impactful. A respondent noted that CS networks thrive when social interaction and shared goals are prioritized. Citizen motivation can be enhanced by recognition mechanisms and clear communication about their role and impact. Anonymization of contributions may encourage greater involvement from citizens hesitant to engage publicly. It was also noted that CS adoption requires careful expectation management and trust-building between citizens and experts. It was advised that working together with NGOs and local partners should help CS initiatives overcome some of the barriers identified, e.g., for reaching different demographics. Here, communication and the design of the study were identified as of greater importance. NGOs were often indicated as interlocutors and mediators between citizen scientists and institutions. Recognition and rewarding of citizens (e.g., conference invitations, authorship mentions, certificates) helps maintain engagement. It was also added that the publication of data in peer-reviewed journals jointly with citizen scientists can boost the legitimacy of the collected data. Along this line, it was emphasized that it is crucial to understand the motivation of citizens to participate in CS projects, as most do not participate primarily for scientific reasons. They emphasized that citizens need to be valued for their contributions and informed about the use of their data to ensure long-term motivation and avoid the risk of losing the engagement of participants. The need for creative community-building methods (e.g., gamified apps, reward-based community tasks, weighted voting) to maintain citizen engagement and the need to adapt communication to everyday citizens through clear and accessible language were reported.

An expert from the Association Citizen Science Italy cited two projects that could be helpful for ENFORCE, namely the OTTERS project,⁴⁶ on scaling up CS with an eye on applicable legislation, and the INaturalist project,⁴⁷ which is a very good example of standardisation for institutional use. The person also recommended the experience of the river contracts where it could be useful to integrate CS, as already happened on some occasions.⁴⁸ The person also mentioned that ECSA's 10 principles on CS⁴⁹ can be a way to standardise the practice. At the same time, they noted that "principles have to be dynamic as citizen science is multiform and evolves; context-specific reflection is needed to bring citizen science to territories, especially in extreme contexts like conflict zones (...) it might not even be citizen science. For example, civic monitoring does not necessarily need to be scientific, it is still civic participation, and this can still be used to alert enforcement authorities." The possibility to build local programs and action for improving procedural awareness for biodiversity protection and environmental compliance was advanced. Another point of relevance emerged on the lack of "a science-driven culture or perspective in the community": as a consequence, the person reported, once more people are participating in science-related activities, and once they receive any scientific reports or scientists are speaking to

⁴⁶See <https://otters-eu.aua.am/>.

⁴⁷ See <https://www.inaturalist.org/>.

⁴⁸ See <https://www.lambrolucente.eu/> and <https://www.lambrolucente.eu/patto-di-collaborazione/>.

⁴⁹ See <https://www.ecsa.ngo/10-principles/>.

them, they are more likely to be engaged. A person stressed the need to bring CS into the curricula of social and hard sciences, to teach students how to collaborate among different areas of expertise, and how to integrate science in territories. The person said: “empathy is something you either have or you don’t, but if you study how to integrate CS into your science and bring science to territories, you can fuel this empathy.”

Concerns about over-reporting, especially where groups are very activist-led, were reported. There can be scepticism internally about the motivations of some reports, perceived as being used to target a particular organisation or company. Some interesting questions raised include: if the result is a scientific publication, what difference would it make to a court which data collection methodologies were used to generate the scientific publication? Conversely, if the aim of a project is to collect evidence for court – would this activity still be considered citizen ‘science’, or is this citizen ‘legal activism’? Would this be mediated by a scientific entity (e.g. funded as a research project), or by a citizen initiative? How to foster a better interaction and exchange of knowledge among CS actors and between CS initiatives and the private sector?

4. Key insights for conceptual framework

4.1 The proposed conceptual framework

Drawing from the analysis in Sections 3.2.1-3.2.3, the initial conceptual framework outlined in Section 3.2.1 is repositioning the relationship between environmental compliance as a living governance process and CS dynamic in each governance phase (promotion, monitoring, assurance, and evaluation). Table 6 provides a structured, comparative synthesis of how CS functions across the four phases of environmental compliance assurance and their corresponding regulatory tiers. It addresses the distinct governance roles that CS can fulfil at each stage, the legal categories that shape its admissibility and institutional uptake, and the barriers and enabling conditions that determine its operational viability. By reading the table horizontally, the reader can trace the functional trajectory of CS across the compliance cycle; by reading it vertically, one can identify the legal-institutional determinants that consistently influence CS integration across jurisdictions and stakeholder groups.

Table 9 - Conceptual framework updated based on interview results

Phase	Tier	Role of Citizen Science	Relevant Legal Categories (generic only)	Main Barriers	Enablers / Needs	Country Examples
Promotion	Preventive	Provides public awareness, early risk signalling, supports participation rights	Access-to-information rules; public participation frameworks; constitutional environmental rights	Low awareness; institutional distrust; limited data access	Intermediaries (NGOs, universities); transparent communication; inclusive formats	Spain (Mar Menor mobilisation); Italy (local CS on emissions); UK (public pressure on EA)
Promotion	Preventive	Supports co-creation and dialogue; identifies issues before formal monitoring	Administrative participation norms; local governance procedures	Political reluctance; low inclusivity; weak outreach	Co-created processes; citizen training; stable contact points	Belgium (local participation); Austria (citizen biodiversity initiatives)
Monitoring	Oversight	Generates local, high-frequency observations; detects anomalies	Administrative monitoring duties; environmental reporting obligations	Variable data quality; lack of standards; digital divide	Standardised methods; metadata preservation; accessible EO data	UK Riverfly; Netherlands sensor networks; Italian methane monitoring
Monitoring	Oversight	Triggers inspections or alerts; helps prioritise enforcement	Inspection systems; early-warning and intelligence frameworks	Workflow gaps; overload concerns	Defined intake channels; triage protocols; mobile reporting tools	Flanders (citizen-triggered cases); UK EA intelligence use
Monitoring	Judicial-adjacent	Supplies preliminary evidence or leads for investigation; sometimes used in litigation	Evidence law; rules on expert validation; free evaluation of proof	Chain-of-custody gaps; metadata loss; perceived bias	Scientific validation; hashing/versioning; expert corroboration	France school air-quality CS case; Italy CS testimony case
Assurance	Corrective	Supports sanctions, corrective orders, and follow-up monitoring	Administrative sanctioning frameworks;	Institutional scepticism;	DRLs; feedback loops; independent intermediaries	Belgium PFAS monitoring; UK sewage incident tracking

			compliance assurance procedures	understaffing; unclear quality thresholds		
Assurance	Corrective	Helps document recurrence of violations and compliance trends	Compliance tracking systems; performance evaluation rules	Data integration problems; fragmented platforms	Interoperable platforms; long-term stewardship	Belgium PFAS blood data; UK volunteer time-series
Evaluation	Oversight	Contributes to system performance indicators and adaptive governance	Policy evaluation cycles; environmental indicator frameworks	Weak feedback loops; no formal CS role in evaluation	Publication of impacts; CS-based indicators; joint evaluation	Spain reforms (Mar Menor); Netherlands dashboards
Cross-cutting	All	Documents environmental inequalities; supports environmental justice claims	Constitutional equality protections; environmental justice norms	Participation bias; privacy/safety risks	Secure platforms; anonymisation; targeted outreach	Italy (Terra dei Fuochi); Iraq air pollution CS
Cross-cutting	All	Acts through intermediaries who translate between citizens and authorities	Administrative mediation roles; NGO standing rules	Lack of trusted brokers; high burden on citizens	University/NGO intermediaries; legal clinics	Belgium (Natuurpunt); Italy (CNR validation)
Cross-cutting	All	Relies on robust digital and audit systems to ensure integrity	Data governance norms; privacy/data-protection rules	Sensor accuracy; EO cost; integrity risks	Calibration; quality checks; provenance tracking	UK/US sensor guidance; Italy EO issues
Cross-cutting	All	Requires Data Readiness Levels (DRLs) to align expectations and admissibility	Evidence quality standards; risk-based monitoring principles	No shared quality language; institutional bias	EC-DRL framework; metadata DRL tagging; joint training	Netherlands/Belgium high maturity; Romania low trust

Environmental compliance provides a structured model for how states secure adherence to environmental rules through four linked phases – promotion, monitoring, assurance, and evaluation.

- Promotion is where compliance begins. It builds awareness, fosters knowledge exchange, and develops the capacities of institutions and communities alike. Compliance becomes meaningful not when it is imposed, but when it is understood as part of collective responsibility and societal values.
- Monitoring ensures that the state of the environment and compliance behaviour are observed with credibility and precision. It combines traditional inspections with new tools such as digital platforms, Earth observation and CS, thereby integrating professional expertise with civic contributions.
- Assurance provides the mechanisms by which compliance is secured. It encompasses cooperative approaches that support voluntary action as well as enforcement measures that hold actors accountable. Effective assurance depends on proportionality and balance: it must deter violations while also enabling constructive and sustainable practices.
- Evaluation closes the cycle by linking actions to outcomes. It ensures that compliance is assessed not only in terms of effort but in measurable results such as reduced pollution, biodiversity recovery, or strengthened forest governance. Evaluation also functions as an institutional learning process, enabling compliance systems to adapt and remain responsive to emerging challenges.

These four phases map onto corresponding regulatory tiers (preventive governance, administrative oversight, corrective action, and judicial-adjacent enforcement) illustrating that compliance is not generated primarily in courtrooms but through upstream systems that clarify obligations, facilitate information flows, generate evidence and trigger proportionate responses. The framework thus conceptualises environmental compliance assurance as a continuum of interdependent mechanisms, each of which contributes incrementally to overall regulatory performance.

When aligned with the theory of change (see section 1.2), the framework becomes a causal architecture. Promotional activities (awareness, guidance, participation channels) are theorised to strengthen the motivations and capacities of duty-holders. Monitoring activities (inspections, digital sensing, Earth observation, CS) reduce information asymmetries by increasing the availability, spatial density and legitimacy of compliance-relevant data. Assurance activities (administrative sanctions, corrective orders, cooperative compliance tools) convert detected risks or breaches into behavioural and institutional adjustments. Evaluation introduces structured feedback loops, enabling continual refinement of rules, tools and organisational practices.

It can be noted that the conceptual framework for environmental compliance assurance, which relates to **promotion, monitoring, assurance, and evaluation**, and places **citizen-based innovation** at its core, is strengthened and operationalized by the ENFORCE glossary. In the area of promotion, glossary entries such as *Capacity Building*, *Citizen Engagement*, *Workshops*, *Co-creation*, and *Policy Gap* demonstrate that compliance promotion is not confined to communication or raising awareness. Instead, it is about creating enabling conditions, equipping institutions and citizens with the agency and skills required to participate meaningfully in

compliance processes. These terms reinforce that promotion must cultivate shared responsibility and active participation, laying the groundwork for compliance cultures that are both voluntary and sustainable. In terms of ENFORCE's work organisation, promotion links directly to knowledge and capacity building, citizen and stakeholder engagement, and project management, creating the foundation for effective compliance across contexts.

The glossary also supports the field of monitoring, capturing a wide range of approaches from *CS* and *Civic Environmental Monitoring* to *Earth Observation*, *AI/Machine Learning (ML) Algorithms*, and *Data Quality* standards. Terms such as *Data Dashboards*, *Spatial/Temporal Resolution*, and *River Health* clarify how compliance monitoring integrates citizen-generated evidence with technical and institutional methodologies. This integration enhances both scale and precision while promoting transparency, legitimacy, and trust between regulators and communities. This integration promotes transparency and legitimacy by making data accessible and actionable. Within ENFORCE, monitoring is connected to the pillars of data, models and tools, case studies, and citizen engagement, where innovation enhances both technical reliability and community ownership of compliance outcomes.

For assurance, understood as both enforcement and cooperative mechanisms, the glossary highlights the legal and institutional backbone through entries such as *Admissible Evidence*, *Environmental Crime*, *Environmental Law Enforcement*, *Agency*, and *Jurisdiction*. These concepts anchor the system in enforceability, demonstrating how rules are upheld through judicial and administrative means. Yet assurance is not limited to punitive action: terms like *Beyond Compliance*, *Voluntary Action*, and *Civic Sentinels* emphasize that assurance must also embrace cooperative and participatory approaches. By recognising the role of citizens and stakeholders as active partners, the glossary situates assurance within a broader governance framework that balances deterrence with legitimacy. Within ENFORCE's framework, assurance relates to compliance approaches, citizen engagement, and sustainability, demonstrating how enforcement can be balanced with legitimacy, cooperation, and trust-building.

The dimension of evaluation is clarified through entries such as *Key Performance Indicators (KPIs)*, *Roadmap for Environmental Compliance*, and *Data Readiness Levels*. These concepts provide the evaluative instruments necessary to make compliance actions measurable, transparent, and adaptive. Evaluation is thus framed not as a static reporting exercise, but as a process of accountability and continuous learning. By linking indicators with outcomes—such as pollution reduction, biodiversity restoration, or detection of illegal logging—the glossary ensures that compliance systems remain responsive to environmental and social change. For ENFORCE, evaluation is embedded in project management, replication, and sustainability, ensuring that outcomes are not only assessed but also scaled and institutionalised.

Finally, the glossary foregrounds citizen-based innovation as a cross-cutting element. Terms including *CS for Compliance Assurance*, *Living Labs*, *Sociotechnical Innovation*, and the *ENFORCE Plaza Toolkit* illustrate how innovation is embedded across all stages of the compliance cycle. By anchoring innovation in citizen engagement, the glossary positions compliance not as a top-down process but as a shared governance practice, where legitimacy and trust are co-produced. This

integration ensures that compliance frameworks remain dynamic, capable of adapting to technological change, societal expectations, and ecological urgency. This directly connects to ENFORCE's pillars of citizen engagement, data, models and tools, and replication and sustainability, confirming the project's role in shaping compliance as both a governance practice and a social innovation.

4.2 The proposed conceptual framework applied to the environmental issues covered by ENFORCE (biodiversity, pollution, logging)

In **biodiversity governance**, promotion is reflected in capacity-building programmes and citizen engagement initiatives that equip communities to participate in species and habitat monitoring. Monitoring is increasingly undertaken through a combination of CS and Earth observation, supported by digital dashboards that integrate local and large-scale data. Earth observation contributes to biodiversity monitoring by providing consistent, large-scale, and high-resolution data, enabling trend analysis over time, early detection of habitat changes or species decline, and improved accuracy and comparability of assessments across regions. Assurance emerges through the legal validation of biodiversity data as admissible evidence in litigation, alongside cooperative measures that encourage “beyond compliance” practices such as habitat restoration. Evaluation relies on biodiversity-specific KPIs, such as population recovery rates or habitat coverage, providing measurable feedback for policy effectiveness.

In the case of **pollution control**, promotion centres on awareness-raising and co-creation workshops that align citizen expectations with regulatory objectives. Monitoring integrates advanced tools such as machine learning algorithms and participatory air and water quality sampling, extending the reach of traditional inspections, while Earth observation enables time- and location-specific detection of illegal waste disposal, air pollution and water contamination (e.g., from agricultural pesticides). Triangulating satellite data with CS observations and ground-based sensor networks further enhances monitoring accuracy and precision. Assurance combines institutional mechanisms — environmental agencies, jurisdictional powers, and criminal law — with cooperative innovation, including citizen reporting platforms and participatory monitoring protocols. Evaluation is achieved through KPIs tracking reductions in pollutants (e.g., NO₂, nitrates), while data readiness levels ensure citizen-generated evidence can reliably inform compliance actions.

For **deforestation and illegal logging**, promotion draws on participatory approaches such as living labs, which bring together authorities, industry, and local communities to design monitoring protocols. Monitoring is strengthened through Earth observation, high-resolution spatial analysis, and civic sentinels who provide on-the-ground reporting of illegal logging activities. Earth observation delivers continuous, large-scale, high-resolution data that supports early detection of deforestation, precise mapping of affected areas, and long-term trend analysis. Combined with AI, it enables predictive analytics and verification of reported activities, complementing ground-based monitoring for more accurate and timely enforcement. Assurance operates through the enforcement of EU due diligence regulations, supported by admissible evidence from traceability

systems and citizen reports, while also recognising voluntary certification schemes as “beyond compliance” mechanisms. Evaluation applies KPIs related to deforestation reduction targets and sustainability indicators, with roadmaps ensuring that practices are replicated and adapted across jurisdictions.

5. Guide for citizens and prosecutors

5.1 From local knowledge to systemic integration: Mapping the legal needs and expectations across the consortium and the case studies

In December 2024, during the first months of the project, we engaged the partners and case studies of ENFORCE to identify legal needs and expectations and shape the following activities related to these dimensions of the project. Below we illustrate some of the results and the relevant considerations.

We started with a mapping exercise using the collaborative online tool Miro. During a dedicated workshop we engaged the partners in two boards, one dedicated to the case studies and one to the legal experts across the consortium’s partners. Below, we indicate the guiding questions for each board:

Questions on the Miro Board for Case Studies

- To which macro-area the environmental issue in your case study belongs? (Participants could situate their case study with its name in one of the sets or at the intersection of the sets; the sets were Pollution / Loss of biodiversity / Forest and conservation / Environmental health impacts / Other macro-area with a request to specify).
- Indicate relevant legislation applicable to your case study.
- Indicate any judicial action or extra judicial action for environmental non-compliance related to your case study (indicate name of case study and reference to action specifying 1) if your organization is in some way supporting it 2) if the CS initiative of your case study has been used to support the action).
- Are there any specific certification mechanisms that the data of your CS initiative in your case study received and that can boost the use of such data for compliance assurance? (indicate name of case study and certification mechanism)

Questions on the Miro Board for Legal Experts

- Indicate existing relevant legislation on which we could currently rely on for promoting the use of CS for compliance assurance (local, national, European).
- Indicate any judicial action (specify if civil, administrative or criminal) or extra judicial action in which CS has been deployed for environmental compliance assurance and the role of your/any relevant organization towards it.
- Indicate any specific certification mechanisms that can support the use of CS data for compliance assurance.

- Indicate conceivable barriers that could prevent the use of CS data for compliance assurance.
- Think of existing legislation which could be amended to integrate CS to make it a recognized approach for compliance assurance, accepted by competent authorities (local, national, European).

The results can be viewed in the snaps below (Figures 5 and 6) and online on the Miro board.⁵⁰ They signalled a useful awareness of the case studies on applicable legislation and a balanced relevance of judicial and extra-judicial actions related to the case studies. The cases are mostly focused on pollution, loss of biodiversity and environmental health impacts. Only one case study is in the forest and conservation area. The legal experts are also very aware of applicable legislation and possible barriers to the use of CS for compliance assurance but have little knowledge of court cases or extra-judicial actions where CS has actually been used to support environmental compliance.

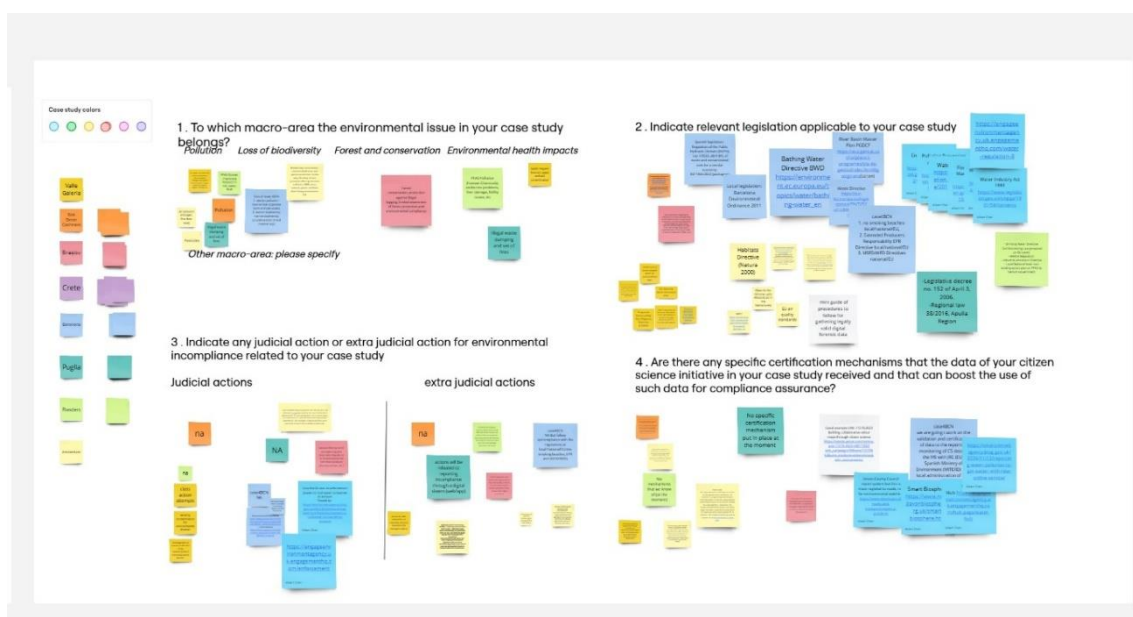


Figure 7 - Miro board for case studies

⁵⁰ See https://miro.com/app/board/uXjVL7kZx1A/?share_link_id=982058912610.

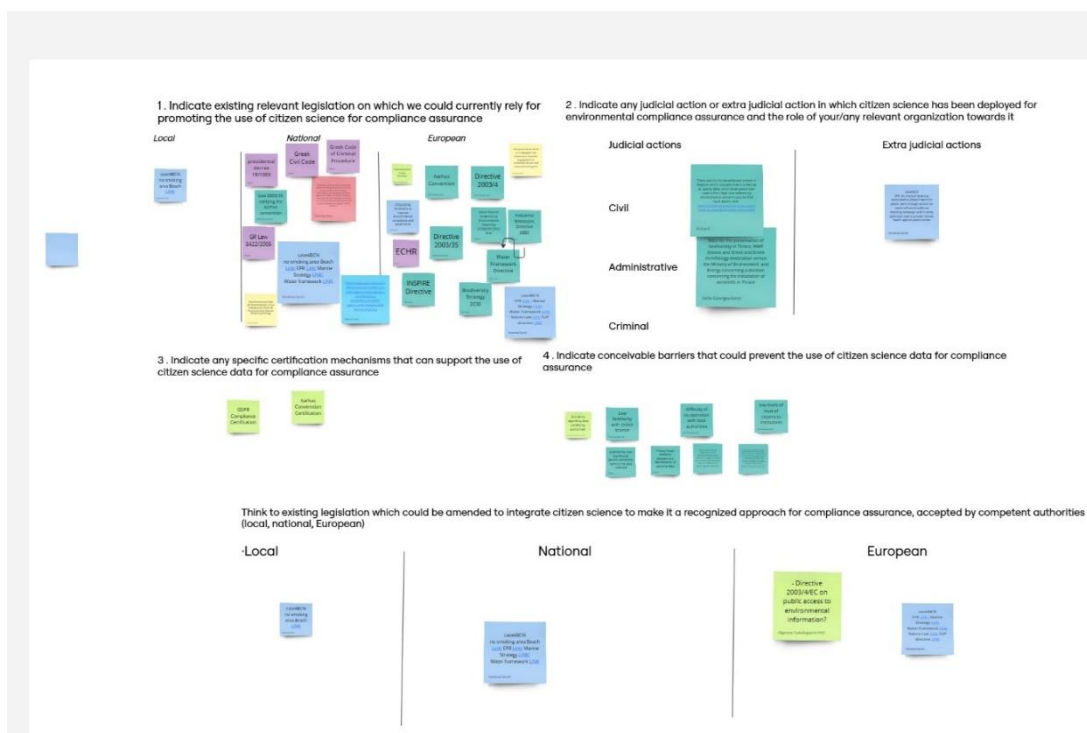


Figure 8 - Miro board for legal experts within the consortium

We also engaged the case studies specifically in a ‘Living Lab Survey’ aimed to assess common grounds in view of the Living Lab implementation within the case studies, curated by partner ENoLL (the text of the survey and selected results are included in Annex IV). The survey was designed to evaluate the foundational elements and development stage of various Living Labs, and to collect insights that shaped the subsequent trainings on Living Lab methodologies, thereby preparing case studies for the creation and operation of Living Labs. Each case study had to submit one completed survey.

The survey consisted of three strands:

1. **Living Labs:** Analysing the case studies knowledge on the approach and assessing their structure and operational dynamics.
2. **Law:** Examining the legal dimension of each case study (in terms of status, capability and aspiration).
3. **Data:** Exploring how data is managed and utilized within the Labs.

The Table, included in Annex IV, illustrates the results of the legal part of the questionnaire. It should be noted that the views expressed by the case studies at the time of the survey, i.e., in November 2024, may have changed to date as the project evolved. An awareness on relevant sectorial legislation was found as a common ground among the case studies, which had mostly performed a mapping exercise of relevant legislation. Knowledge on existing judicial or extra-

judicial actions related to the case varied across the case studies. A varied attitude was recorded in terms of case studies' inclination to enable a legal and/or extra judicial action through their case study, which is a noteworthy point. Most of the case studies were facing challenges in relation to applicable legislation and/or from a procedural perspective. Some of the barriers cited include procedural limitations; time and resource constraints preventing the access to legal expertise; a general civic distrust towards legal action; difficulties with proving the liability of an operator or perpetrator; limited responsibility of corporate persons/administrative bodies; lack of effective and uniform application of the law; lack of expertise (no special environmental police/environmental courts); fragmented or absent legislation; unclarity of legislations and different interpretation of the law; few precedents on citizen science used in courts.

5.2 Providing guidance to citizens and prosecutors

Key insights from the data collection and review performed across T2.1-2.2-2.3

Our review points to the need for CS to become structurally and systematically applied within the normal operation of environmental compliance monitoring and control systems. CS projects usually originate at the local level, in response to specific issues or critical situations that exist locally. This is also because environmental problems are often more noticeable and 'felt' at the local level, and because certain phenomena, such as pollution, can also be very localised. However, if CS is to be taken to a 'system' level and structurally incorporated into environmental compliance management, individual projects and CS in general need to be scaled up to regional, national and supranational levels (upscaling). However, there is another issue that is also relevant: how can knowledge, techniques and good practices, consolidated at national or regional level, be transferred to the local level in such a way as to involve local citizens in a structured and organic manner, as they are the main actors who must carry out CS. The key words are involvement, collaboration, sharing, to create a positive feedback loop between the different levels involved.

It is necessary to establish regular channels of communication through digital tools and platforms, social media, media, and regular workshops or conferences. It is essential to show the impact of local contribution on regional findings, and, conversely, demonstrate how the results and analyses carried out at national/regional level can have an impact or be useful at local level as well. Whenever possible, it is useful to adopt co-creation and participatory CS approaches, and it is also useful to build a shared and collaborative software platform on which the various levels can operate.

An important element is continuous training, especially on field, conducting periodic sessions, workshops, and seminars and practical training on new techniques and technologies, providing a support service, also for clarifications and assistance, easily accessible through various channels (telephone, email, online chat). Experts at regional, national or supranational level should act as 'mentors' by encouraging the sharing of knowledge, experiences, problems, mistakes and problem solving.

It is also necessary to identify methods for monitoring and evaluating the effectiveness of applying CS for compliance assurance at the local level, and to ensure that the correct methodologies and techniques defined centrally are correctly applied at the local level, while at the same time taking advantage of and capitalising on any feedback, positive and negative. Finally, local characteristics must be assessed and guaranteed in terms of the environmental, socio-economic and cultural context, as well as in terms of legal aspects and established practices, so that, national/regional methods are adapted to local specificities as far as possible. Where analysis at national or even supranational level is necessary/useful, it is essential that local surveys are conducted according to standard methods, formats and codes so that they can be compared.

Based on our data collection and review, we indicate below a series of best practices that should be followed to make the data collected through citizen science more reliable and usable in a systematic and structured manner.

Chain of custody: Citizens should document the evidence's original state using different methods such as notes, sketches, photos, or videos; they should maintain a complete chain of custody for all items and ensure that evidence are relevant and legally obtained; it would be preferable to use checklists to ensure all principles and practical steps are followed.

Quantitative data vs qualitative data: Data collected by citizens can be qualitative (e.g., description of a smell) or quantitative (e.g., measure of temperature). If instruments are used to take quantitative measurements, it is important to check that they are correctly calibrated. Whenever possible, quantitative measures are preferable, but when it is not, for example because suitable instruments or capabilities are unavailable, participation should still be encouraged, even if limited to qualitative observations. It is preferable to have more frequent sampling and greater participation, even if only with qualitative observations, than having a few quantitative measurements. Overall, qualitative data can add context which purely quantitative data often lacks, and this contribution should be recognized.

Data and time: It is useful, often necessary, to always note the date and time of the observation. Temporal sampling is also an important element in the observation of a phenomenon. For certain phenomena, it would be useful if the frequency of temporal observation were not sporadic (one-off) but carried out at defined intervals or at different times in order to analyse any periodic fluctuations. The periodicity and frequency of detection should always be defined at the design stage, bearing in mind that, given that participants are typically volunteers, it is often difficult or even counterproductive to bind them to detect phenomena at specific times or with defined periodicity.

Location: Just as measurements must be placed in time, they must also be placed in space, preferably using simple geolocation (e.g. as, provided by Google Maps), but also by photographing or filming the survey location and/or providing a textual description of the position. Where it is necessary to process the measurements using geospatial criteria, it is useful to establish in advance the methods for geolocating the measurements themselves, in line with the tools and capabilities of the participants.

Coding: To facilitate subsequent processing, it is useful to define a centrally shared coding system to identify detectors and measurements. This also ensures the privacy of the detector, should it not wish to appear in reports and/or processing. Where a tool is used for measurements, coding should be guaranteed by the tool itself. A standardized system to track documents and digital information should be used.

Preserving and documenting the scene using multiple methods of documentation: In some cases, it is necessary not to touch or move the evidence, but to leave it unchanged, unless it is necessary to take a sample. In any case, it is useful to photograph or film the scene of the survey, if necessary, before and after the survey, or describe it using different methods such as notes or sketches, photos, or videos. The details of the scene should be described and recorded.

Security and legality: All documentation collected and findings should be kept carefully and not disclosed except to competent persons (authorities, lawyers, researchers, etc.). In the case of digital media, it is always useful to make a backup copy and keep it unaltered over time and reproducible. Very important: the survey must not violate any laws; for example, it is not acceptable for a survey to be carried out on private property without the prior informed consent of the owner.

Checklists: It is useful to define a checklist that guides citizens in their investigations and allows them to track all relevant information and ensure that all the procedures listed above have been followed. Where a tool is used, it is useful for the checklist to be directly implemented in the tool itself.

Collaboration: Although citizens can carry out civic monitoring on their own and without specific experience, it is nevertheless useful for a variety of reasons to find ways of collaborating or forming associations with other citizens, involving researchers or experts in the field or related topics, and establishing contact with associations or organisations operating in the sector: collaborative CS allows efforts to be shared, useful information/skills to be acquired, consistency in carrying out surveys to be maintained over time, one's approach to monitoring to be validated, and solutions and methods to be shared.

The table below provides a synthesis of key needs mapped through the study contained in this report, the connection with technological needs and their potential impact on ensuring that CS data are admissible for environmental compliance purposes.

Table 10 - Synthesis of requirements, methodological needs and technological solutions to ensure that citizen science data can be used for compliance purposes.

Requirement dimension	Methodological need mapped	Technological solution	Relevance to admissibility
Data integrity & provenance	Chain of custody documentation; metadata preservation.	Secure, time-stamped applications; blockchain/hashing mechanisms.	Ensures data is untampered and traceable from source to court.

Scientific validation	Calibration against reference sensors; expert corroboration.	Automated co-location analysis; AI/ML algorithms for quality control.	Addresses institutional distrust regarding data reliability.
Compliance	Adherence to national procedural law; GDPR requirements.	Anonymization protocols; integrated ethical compliance kit.	Mitigates risks of evidence exclusion based on rights violations.
Interoperability	Common data standards; integration with official datasets.	INSPIRE directive alignment; Green Deal Data Space Connector.	Allows seamless comparison and integration with institutional evidence.

Table 7 results indicate that the admissibility of citizen science data in environmental compliance and enforcement does not depend on a single legal or technical requirement. Instead, **it depends on how several conditions are met across the lifecycle of the data**. Data integrity and provenance, scientific validation, compliance with legal and procedural rules, and interoperability with institutional datasets all contribute to whether citizen-generated data can be used in administrative or judicial proceedings. These conditions arise at different moments and involve different actors. Adopting accurate practices at the stage of data collection is central to ensure integrity and traceability, while later stages focus on validation, corroboration, and procedural assessment by authorities and prosecutors. Interoperability enables citizen science data to be linked with official monitoring systems and thus increases its practical relevance. Overall, the results show that **admissibility is shaped by the interaction of multiple practices** rather than by isolated actions. This explains the need for guidance that is tailored to different actors, while also requiring a broader view that shows how these practices connect across the system. The following subsections address this relationship.

Certified and Trusted Data Providers and Evidentiary Use

As outlined in the review towards ECCI conceptual framework development (Section 3), effective environmental compliance depends not only on enforcement mechanisms, but also on the availability of environmental data that are reliable, traceable, and legally usable across administrative and judicial contexts. When linking this framework to the guidance developed for data providers and citizens, the notion of certified data providers is therefore understood within existing EU legal and governance arrangements that already shape expectations regarding data quality, transparency, and evidentiary usability.

At EU level, the **INSPIRE Directive** (Directive 2007/2/EC)⁵¹ provides the clearest illustration of how environmental data are expected to be structured for reuse across public administration, regulatory oversight, and, where relevant, judicial proceedings. INSPIRE establishes mandatory requirements for harmonised metadata, interoperability, and documented data quality for spatial

⁵¹ See <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007L0002>.

environmental datasets held by public authorities. In doing so, it embeds traceability, consistency, and technical standardisation as prerequisites for meaningful reuse, including in compliance and enforcement contexts. Within this governance landscape, **the European Environment Agency (EEA)**⁵² emerges as a paradigmatic trusted data provider. EEA datasets are produced under documented methodologies and quality assurance and quality control procedures and are accompanied by transparent metadata, which enables independent verification of provenance and comparability. This explains why EEA data are routinely used in EU policy evaluation and infringement proceedings.

Similarly, the **Copernicus Earth Observation Programme**⁵³ illustrates how large-scale environmental data infrastructures can support compliance monitoring and enforcement. Copernicus provides satellite-based and in-situ data on land use, air quality, climate change, and marine environments through standardised processing chains and open access policies, supported by detailed quality and uncertainty documentation. These features make Copernicus data increasingly relevant for evidentiary use in areas such as deforestation detection and pollution monitoring.

The review also considers participatory and citizen-generated data. In this context, the **European Citizen Science Association (ECSA)**⁵⁴ has articulated widely cited principles on transparency, data quality, and ethical practice, which serve as reference points for assessing the credibility of citizen science outputs (Haklay et al., 2021). Academic research confirms that citizen science data can meet scientific and legal standards when collected under structured protocols and supported by appropriate metadata and validation mechanisms (Haklay, 2013; Kosmala et al., 2016; Loiselle et al., 2024).

Taken together, these examples support an understanding of certified data providers as entities whose data governance practices increase the likelihood that datasets can reach higher levels of data readiness for regulatory and evidentiary use. This understanding aligns with the concept of **Data Readiness Levels (DRL)**, which distinguishes between the mere availability of data and its preparedness for analytical and decision-making contexts (Lawrence, 2017). DRL assessment helps to clarify that even data originating from trusted providers may vary in evidentiary readiness and may require additional contextualisation or expert interpretation in judicial proceedings.

From an evidentiary perspective, the review confirms that data from certified or trusted providers do not enjoy automatic admissibility in court. Rules on admissibility and probative value remain governed by national procedural law, subject to EU principles such as effectiveness and the right to a fair trial. Data from institutional providers may be more readily assessed by courts because safeguards relating to provenance, integrity, and documentation are typically embedded in their governance practices, but judicial scrutiny remains case-specific. Consequently, reference

⁵² See <https://www.eea.europa.eu/en/analysis>.

⁵³ See <https://www.copernicus.eu/en/access-data>.

⁵⁴ See <https://www.ecsa.ngo/10-principles/>.

frameworks, lists, or standards (such as ISOs) that are not formally integrated into EU law cannot confer binding legal status or automatic admissibility on data sources. Academic literature emphasises that voluntary frameworks may support assessments of due diligence or organisational capacity, but do not substitute for statutory compliance or judicial evaluation (Kingston, 2021; Alblas & van Zeven, 2023).

Against this background, the creation of an EU-level initial list of certified and trusted data providers is understood as an informational and orientative reference tool, derived from the review and legal analysis. Its purpose is to enhance transparency and legal certainty for courts, prosecutors, and citizens navigating an increasingly complex data ecosystem, particularly in light of the limited familiarity of some first-instance courts with non-traditional evidence such as citizen-generated data and remote sensing outputs. The list does not replace judicial assessment, but supports it by identifying data providers whose governance practices are more likely to facilitate evidentiary scrutiny.

Within the ECCI framework, this legal architecture provides an important reference point for **guidance addressed to both data providers and citizens**. For data providers, it clarifies the governance and documentation conditions that enhance the legal usability of environmental data. For citizens, it illustrates how participatory or citizen-generated data can increase their potential relevance for compliance and enforcement when collected and documented in ways that align with these established principles. In this sense, the concept of certified data providers does not introduce a new legal category, but reflects the application of existing EU expectations regarding data governance to an increasingly diverse ecosystem of environmental data sources.

In this view, Tasks 2.1 – 2.3, linked to the present Deliverable are positioned at the conceptual and analytical core of the project, with the primary objective of reviewing and synthesising evolving policy, strategic, theoretical and legislative approaches to environmental compliance and innovation. Within this context, the development of guides for citizens and prosecutors represents a deliberate methodological choice. The decision to begin with one-pager formats reflects the exploratory and integrative nature of the aforementioned tasks. One-pagers function **as boundary artefacts that translate abstract legal, policy, and innovation concepts into concise guidance points**. In this way, they facilitate early alignment among the diverse disciplinary communities involved in the project, including legal scholars, environmental scientists, technologists, policy analysts, and citizen science practitioners. This early alignment is a necessary precondition for establishing a shared conceptual framework and common language across disciplines, and directly reflects the ENFORCE Glossary produced⁵⁵.

From a theoretical perspective, environmental compliance is increasingly understood not solely as a top-down regulatory process, but as a distributed socio-technical system in which public authorities, regulated entities, citizens, and technological infrastructures interact. One-pager guides provide an entry point into this system by articulating compliance in terms of concrete behaviours, decision points, and responsibilities, without prematurely fixing legal interpretations

⁵⁵ See <https://doi.org/10.5281/zenodo.17901267>

or national implementation details. This approach reflects contemporary scholarship on regulatory innovation (Clausen et al., 2023) which emphasises the need of an enabling framework that assesses the costs of compliance.

This form of guidance supports the project's emphasis on citizen science and citizen-generated evidence by making explicit, at an early stage, the types of observations, documentation practices, and behavioural boundaries that are both meaningful for enforcement and appropriate for non-professional actors. Its concise nature allows these elements to be tested and discussed with stakeholders without prematurely fixing ethical, legal, or technical requirements. In parallel, the guidance introduces citizens and enforcement actors to the conceptual implications of integrating citizen-originating evidence into compliance processes, without providing jurisdiction-specific procedural instructions. This supports early institutional reflexivity and prepares the ground for more detailed operational guidance in subsequent work packages.

Guidance for citizens: strengthening participation in environmental compliance

Citizens must be equipped with the knowledge and tools necessary to produce reliable, standardised data, and to understand their rights of participation. In practice, this requires more than awareness: it involves training, access to user-friendly tools, and opportunities to connect with institutional actors.

Promotion begins with equipping communities to act. In biodiversity governance, this may take the form of workshops that train volunteers to identify bird and plant species using mobile apps linked to EU biodiversity databases. In pollution control, citizen groups may be introduced to low-cost air quality sensors, allowing them to generate localised data that complements state monitoring stations. For illegal logging, local communities can be trained to recognise irregularities in timber transport and to use mobile reporting platforms to notify authorities.

Monitoring represents the main practical contribution of citizens. Standardised protocols ensure that their data is credible. For example, water sampling kits used in participatory river monitoring projects are designed to meet scientific standards, making the results admissible in policy discussions and, potentially, in court. In forest governance, Earth observation platforms combined with "civic sentinel" observations can detect and report illegal felling. Here, practical guidance emphasises that data collection must follow agreed methods, including timestamped photos, geo-referencing, or use of digital dashboards to maintain reliability.

Citizens also play a role in **assurance**. While enforcement is primarily institutional, civic participation strengthens its reach and legitimacy. Citizen reports, when documented through standard procedures, can form the basis of investigations. Beyond reporting, citizens contribute to "beyond compliance" initiatives such as local habitat restoration, which reinforce cooperative models of governance.

Evaluation closes the loop by providing feedback on results. Citizens can observe whether compliance actions lead to cleaner air, healthier rivers, or reduced logging in their regions. Practical indicators (such as visible improvements in local biodiversity, reductions in air

pollutants measured by sensors, or transparency reports from timber companies) help communities assess whether their participation yields tangible change. In this way, citizens shift from passive observers to active compliance partners, reinforcing both accountability and legitimacy in environmental governance. However, it should be considered that evaluation often involves interpretation which can be a potential source of disagreement over the meaning of the results. Involving peer CS communities and scientific experts in the evaluation of results can be a way to mitigate the risk of disagreement or in any case decide upon them.

Guidance for prosecutors: using citizen-generated data for environmental enforcement

Prosecutors must be trained to recognise and deploy citizen-generated data in ways that strengthen, rather than undermine, legal robustness. This requires familiarity with digital traceability systems, participatory monitoring protocols, and evidentiary standards applicable to environmental litigation.

In terms of **promotion**, prosecutors can contribute by signalling openness to non-traditional evidence and engaging in training sessions with CS groups and NGOs. For example, when prosecutors communicate that properly documented citizen data may be considered in investigations, it encourages higher-quality reporting and strengthens trust between institutions and the public.

Monitoring is not conducted by prosecutors but understanding how it works is critical. In pollution cases, this means knowing the scientific methods behind participatory air and water monitoring, so that datasets can be evaluated for admissibility. In logging cases, prosecutors must familiarise themselves with blockchain-based timber traceability systems, which can establish supply chain irregularities. In biodiversity cases, prosecutors should be aware of protocols used to validate species or habitat observations so they can distinguish credible datasets from anecdotal claims.

The central prosecutorial role lies in **assurance**. Here, citizen data becomes a potential evidentiary resource. In practice, this might involve:

- Using geo-referenced citizen photos and satellite data to support a case of illegal logging.
- Introducing validated air quality data from citizen sensors as corroborative evidence in industrial pollution litigation.
- Referring to citizen-generated biodiversity monitoring results in cases involving breaches of habitat protection laws.

To ensure robustness, prosecutors must verify chain-of-custody procedures, confirm that protocols were followed, and integrate citizen data with official monitoring records. They must also anticipate defence challenges by ensuring that evidence standards are met.

Evaluation enables prosecutors to assess broader outcomes of their work. Beyond case-by-case prosecutions, they can track whether reliance on citizen-generated evidence leads to more successful enforcement, whether it acts as a deterrent to polluters or illegal loggers, and whether

it enhances public trust in environmental justice. For example, a measurable reduction in repeat pollution offences following prosecutions supported by citizen data provides a clear performance indicator.

Through ENFORCE, prosecutors are provided with methodological guidance, sector-specific case examples, and tools for integrating citizen data. In practice, this strengthens enforcement capacity by expanding the evidentiary base, while also reinforcing public confidence that compliance systems are fair, transparent, and responsive to collective concerns. This guidance, however, is necessarily **actor-oriented**: it supports prosecutors in exercising their specific institutional functions, in the same way that guidance addressed to citizens supports lawful and effective participation.

Reports as Analytical Synthesis Tools for Judicial Enforcement

Guides addressed to citizens and prosecutors outlined above and presented in Annex I translate the legal and conceptual analysis into role-specific guidance, focusing respectively on lawful data generation and evidentiary assessment. By design, these guides operate at the level of individual action as they explain what specific actors should consider or do in relation to environmental data. What they do not provide is a system-level synthesis of how legal conditions, data sources, and evidentiary practices interrelate.

It is therefore crucial to support the development of reports that will fill this analytical gap. In principle, these reviews should contain a structured consolidation of three elements already identified in the deliverable:

- the legal conditions governing the use of environmental data;
- the characteristics and limitations of different categories of data sources, including institutional, certified, and participatory sources; and
- the implications of these elements for evidentiary use in the 4th tier of environmental compliance (see Table 5).

In practical terms, the reports should present comparative and cross-cutting explanations rather than step-by-step guidance. They should explain, for example, how the same legal requirements (such as legality of collection, traceability, or integrity) apply differently across data sources, and how these differences affect evidentiary assessment with a particular focus on citizen science data. They should also identify recurring patterns and constraints observed across the analysis, such as common reasons why non-traditional data may be accepted, questioned, or excluded in legal settings.

In particular, for prosecutors, the report should articulate how different data sources align with prosecutorial evidentiary reasoning, clarifying points at which source characteristics intersect with evidentiary thresholds and corroboration practices. For citizens, the report should explain how individual data collection practices connect to broader legal and institutional processes, thereby situating participatory action within the overall evidentiary system.

More generally, the reports will function as reference syntheses. They will not repeat the analysis, nor replace the guides. Instead, they will organise and contextualise existing findings into a coherent account of how environmental data moves from collection, to validation, to potential legal use within established legal frameworks.

6. Conclusion: a roadmap⁵⁶

The ENFORCE project aims to provide **comprehensive support for the systematic implementation of citizen science (CS)** as an effective means of achieving and maintaining environmental compliance. The ENFORCE roadmap presented in this section provides a dynamic, structured, phased strategy for strengthening environmental compliance assurance within the project. It translates the conceptual framework (promotion, monitoring, assurance, evaluation) into a sequenced programme of institutional, technological, and participatory actions.

Each stage corresponds to specific regulatory tiers (preventive, administrative oversight, corrective action, cross-tiered) and links the project's Specific Objectives and Ambitions. Together, they articulate a theory of change in which improved awareness, enhanced environmental governance, strengthened evidence pathways, and durable innovation infrastructures lead to measurable gains in compliance performance. To function as a genuine roadmap rather than a descriptive outline, the document begins by diagnosing the problem it seeks to solve: fragmented monitoring systems, conceptual uncertainty surrounding citizen-generated evidence, and the lack of structured pathways linking detection to enforcement. This baseline analysis establishes the starting conditions against which progress can be measured and clarifies why a phased transformation is required.

The project analyses legislation and doctrine on environmental jurisdiction in different countries, thus allowing for the reuse of experiences or their adaptation to the context under consideration, while broadening awareness of the opportunities and limitations offered by current legislation and case law. Furthermore, it defines KPIs useful for assessing the effectiveness and appropriateness of the methods implemented at organisational, technical, procedural and legal level. All the results (methods, knowledge, datasets, tools as well as best practices and success stories) are collected in one place, the **ENFORCE Plaza**, so that they will be available to all interested actors.

ENFORCE tackles CS applied to environmental compliance from different points of view, broadening the scope of CS so that it is no longer considered a “niche” methodology but can be **structurally incorporated into socio-scientific and legal practices and procedures**, particularly through a conceptual and analytical framework to connect Environmental Compliance through Citizen participations and Innovation actions (ECCI) and Impact Indicators.

⁵⁶ This section was discussed and refined during the ENFORCE General Assembly held in Crete in October 2025.

The aim is to bring CS out of research projects and into society, politics, legislation, jurisprudence and administrative practices. The ENFORCE project also seeks to move beyond awareness-raising and towards **empowerment**. Its mission is to equip both citizens and public authorities with knowledge, tools, and confidence to mainstream CS for environmental compliance assurance and policy agenda setting. This ambition underpins the co-creation of a pan-European collaboration and innovation hub that enables ECCI. The **roadmap** provides strategic orientation for project partners and innovators. Based on the theoretical grounding explained in the present deliverable, it links conceptual advances to measurable outcomes and charts a pathway toward a sustainable, participatory, and innovation-driven compliance culture. The roadmap is structured in **four interconnected steps**.

The steps are interdependent: Step 1 creates the conceptual clarity needed for Step 2; Step 2 produces validated CS data required for Step 3; Step 3 generates enforcement outcomes and methodologies that can be institutionalised in Step 4.

Step 1: Consolidating Knowledge and Conceptual Clarity (Building a shared foundation of knowledge contributing to Promotion/Preventive Governance)

Environmental compliance is reframed as a dynamic governance process that integrates legal frameworks, technological advances, and citizen participation. ENFORCE advances this conceptual clarity through the development of its conceptual framework, which partners and innovators can use to produce practical engagement materials, awareness-raising content, and targeted information campaigns. By harmonising understanding across stakeholders, this step ensures that partners, innovators, and authorities operate within a coherent framework capable of guiding both research and practice. In this context, the creation of a compliance culture that transcends formal legal duties is enhanced. Partners are encouraged to invest in awareness-raising campaigns, capacity-building programmes, and participatory governance structures. Innovators should design tools that are accessible, user-friendly, and capable of engaging communities in co-creation.

This first stage addresses the challenge that environmental authorities, inspectors, and prosecutors often operate without shared definitions of citizen-generated data, without clear guidance on how such information fits within environmental law, and without a common conceptual language to integrate innovation into compliance practice. ENFORCE responds to this by creating a harmonised conceptual and legal foundation. Partners specialising in environmental law and governance prepare analyses on admissibility, monitoring norms, evidence pathways, and regulatory obligations. These materials are made available through the Knowledge Plaza the project's central hub for legal and methodological resources. At the same time, Living Labs establish long-term engagement strategies with citizens and local actors, while co-creating planning tools for voluntary compliance, early-risk detection, and behaviourally informed engagement. In this stage, compliance promotion is not limited to awareness-raising; it is reframed as a shared societal responsibility anchored in clarity, trust, and institutional confidence enabling also the case studies to situate their actions in the different environmental compliance dimensions. This stage operationalises the preventive tier of compliance assurance by ensuring

that actors understand their obligations, the legal meaning of citizen-generated information, and the institutional roles required for effective collaboration. Without this shared foundation, later stages of monitoring and enforcement cannot be reliably scaled.

Key Outputs:

- A common conceptual and legal framework clarifying how citizen-generated information interacts with environmental regulation and evidence standards.
- Long-term citizen engagement strategies that make use of engagement methods, and participatory workshops.
- Co-created plans for identifying and preventing environmental risks before they escalate into violations.
- A shared reference system for inspectors, agencies, innovators, and citizen groups.

Principles to guide Impact Indicators:

- Availability of information and engagement materials per environmental compliance sector towards more consistent use of terminology and methodological standards across authorities
- Evidence that public authorities are reducing conceptual uncertainties in engaging with CS
- Greater confidence among institutions in accepting citizen-generated data.
- Growth in the number and variety of citizen participants.
- Stakeholder analysis and dissemination strategies.
- Documentation of good practices.
- Compilation of datasets on providers of admissible evidence.

Step 2: Strengthening Monitoring Capacity and Data Reliability (contributing to Monitoring/Administrative oversight)

This step translates conceptual clarity into operational capability by expanding the environmental intelligence system on which all subsequent enforcement activity depends. The practical mechanisms making citizen participation impactful. Monitoring is enhanced through the deployment of CS platforms, Earth Observation tools, and explainable AI. Here, the roadmap calls for the integration of traditional inspections with socio-technical innovations, ensuring both credibility and scale. For citizens, this step delivers training programmes and participatory platforms that elevate their role from passive observers to active knowledge producers. For prosecutors and authorities, it provides methodological instruments to evaluate, validate, and integrate citizen-generated evidence into judicial and administrative processes.

Monitoring remains the weakest link in many compliance systems, constrained by limited resources, restricted spatial coverage, and episodic inspection cycles. To address these structural gaps, ENFORCE develops an integrated monitoring framework combining:

- citizen-generated environmental observations,
- in-situ sensors and field-based measurements,

- Earth Observation data from satellite systems,
- environmental risk metrics and early-warning indicators, and
- transparent machine-learning models that explain anomalies and produce traceable outputs.

A key innovation is the Environmental Compliance Data Readiness Level, a structured method for assessing whether environmental data – regardless of source – are sufficiently verifiable, traceable, and interpretable to support compliance actions (to be further developed under T2.5). This framework allows citizen-produced data to progress from raw observations to validated intelligence suitable for administrative or judicial use. These developments transform monitoring into a continuous multi-source system that is geographically extensive, timely, and capable of scaling across countries and thematic domains.

Key Outputs:

- Guidelines for collecting data that meet the principles of Findability, Accessibility, Interoperability, and Reusability and DRL assessment
- Harmonised quality standards enabling citizen-generated and satellite-derived environmental observations to be legally interpretable.
- Suitability of CS methods and ECCI tool.
- Data-integration workflows that place CS, sensors, and Earth Observation systems alongside each other.
- Early-warning systems that detect pollution spikes, habitat loss, or illegal deforestation before they escalate.

Principles to guide Impact Indicators:

- Increased spatial coverage of monitoring due to distributed citizen participation.
- Improvement in the data-readiness scores of citizen-generated datasets.
- Close collaboration with regulators to address the admissibility of data levels and ENFORCE contribution.
- Faster recognition of environmental risks or violations.
- Documented use of ENFORCE monitoring tools in planning inspections and investigations.

Step 3: Supporting Enforcement Pathways (Bringing innovation in enforcement practice contributing to Assurance/ Corrective action and judicial-adjacent enforcement)

Step 3 connects the expanded monitoring to actual regulatory action by developing structured, legally credible pathways for converting observations into administrative or judicial measures. Without these pathways, improved monitoring would not lead to improved compliance.

ENFORCE fosters capacity-building workshops for prosecutors, investigators, and judges, equipping them to interpret and apply digital and citizen-generated evidence. In this phase, the roadmap calls for balancing cooperative compliance with credible enforcement. Legal robustness must be combined with participatory legitimacy. Simultaneously, pilot initiatives on citizen reporting and pre-crime risk assessment demonstrate how citizen engagement can deter non-

compliance and trigger timely investigations. The EC-DRL scale (Data Readiness Level for Environmental Compliance) ensures that evidence passes through a validated pipeline, safeguarding robustness in judicial settings and ensuring that CS strengthens – rather than undermines – legal procedures.

A central difficulty in environmental compliance across Europe is that monitoring and enforcement often operate as disconnected domains. Even when violations are detected, they rarely translate into corrective measures or prosecutions because of unclear evidence pathways, limited cross-agency coordination, and uncertainty about how to validate environmental data. At the same time it should be taken into consideration that assurance pathways encompass: (i) pre-assessment and verification, where raw observations are checked for accuracy, provenance, and legal relevance; (ii) administrative assessment, in which competent authorities evaluate whether verified observations constitute non-compliance under applicable environmental rules; (iii) administrative response, including corrective orders, warnings, sanctions, or other remedial measures; and, where warranted, (iv) judicial-adjacent or judicial escalation, in which cases supported by admissible evidence proceed to prosecutorial review, litigation, or court decision

Key Outputs:

- Evidence-readiness templates, admissibility checklists, and structured documentation protocols accessible through the ENFORCE Plaza.
- Workshops for citizens, inspectors, preliminary investigators, prosecutors, and judges on collecting, interpreting, and using environmental evidence.
- Reports demonstrating how cross-sectoral databases can be used to detect patterns of non-compliance.
- Guidance for ensuring that validated citizen-generated data can support administrative sanctions or judicial action.

Principles to Guide Impact Indicators:

- Development of fair, reusable, and interoperable (FAIR) datasets.
- Demonstration of evidence admissibility in judicial processes.
- Documentation of “success stories” where CS supports enforcement.
- Shorter intervals between detection and corrective measures.
- Higher acceptance of citizen-generated or digitally processed evidence in administrative and judicial settings
- Clear examples where ENFORCE tools and methods contributed to enforcement support.

Step 4: Scaling and Mainstreaming through the ENFORCE Plaza (contributing to Evaluation/System learning and continuous improvement)

Step 4 provides the institutional mechanism that guarantees the durability, scalability, and cross-border applicability of all outputs generated in earlier phases. It transforms temporary project innovations into a permanent ecosystem that authorities, citizens, and innovators can use beyond the project lifecycle. The ENFORCE Plaza functions as the one-stop hub for Environmental

Compliance through Citizens and Innovation, hosting dedicated *sub-plazas* for citizens, data, knowledge, and tools. This digital and institutional hub consolidates resources, facilitates cross-border exchange, and ensures that CS becomes embedded in mainstream compliance culture across Europe. The Plaza also supports Living Labs as participatory mechanisms where citizens, authorities, and innovators co-create solutions and test approaches in real-life contexts. The final stage ensures that the innovations generated by ENFORCE do not remain temporary or project-bound. Instead, they are institutionalised through a long-lasting infrastructure – the ENFORCE Plaza – designed to respond to evolving regulatory needs, technological advances, and societal expectations.

The Plaza is organised into four interconnected components:

- Data Plaza, providing validated and certified environmental datasets and access to the Data Readiness Level system;
- Tools Plaza, offering explainable artificial intelligence models, spatial-intelligence workflows, and visualisation instruments;
- Citizens' Plaza, supporting ongoing engagement, reporting channels, and Living Lab structures;
- Knowledge Plaza, hosting legal guidance, training materials, good-practice registries, and replication tools.

Key Outputs:

- A one-stop European platform for environmental compliance through citizens and innovation.
- Replication guidelines enabling authorities across Europe to adopt ENFORCE tools and methods
- Policy recommendations for integrating Earth Observation, CS, and machine-learning systems into environmental legislation.
- A sustainable community of users, including authorities, innovators, citizens, scientists, and civil society organisations.

Evaluation activities identify impact indicators such as reduced pollution, improved biodiversity conditions, decreased detection times, and enhanced institutional confidence. Lessons learned feed back into the Living Labs, enabling refinement of methods and broader adoption.

Principles to Guide Impact Indicators:

- Training programmes and integration of citizens in engagement activities.
- Uptake and use of data, knowledge, and tools across sub-plazas.
- Evidence of participation through Living Labs and collaborative pilots.
- Uptake of ENFORCE methodologies in national procedures or regulatory updates.
- Documented improvements in compliance attributable to ENFORCE-supported practices.
- Evidence usage in judicial processes.
- Expansion of participatory compliance mechanisms beyond the project consortium.

Table 11 - ENFORCE Results Framework linking outputs, outcomes, and impact indicators directions across the four roadmap steps.

Roadmap Step	Output Indicators	Outcome Indicators	Impact Indicators Directions
Step 1 – Consolidating Knowledge & Conceptual Clarity	Information materials, shared terminology, stakeholder mapping, datasets of admissible evidence providers	Stakeholders use shared concepts; authorities and innovators apply dissemination strategies; improved cross-partner alignment	Information and engagement materials available across compliance sectors; documented good practices; structured datasets support transparency
Step 2 – Strengthening Monitoring Capacity & Data Reliability	Citizen science platforms, EO tools, explainable AI components, training programmes, proposed monitoring standards	Increased validated datasets; authorities integrate socio-technical tools; citizen data enters evaluation workflows	Higher number and quality of datasets/models; adoption of innovative monitoring standards; increased reliability and admissibility of citizen-generated data
Step 3 – Supporting Enforcement Pathways	Capacity-building workshops, validated EC-DRL scale, citizen reporting pilots and risk detection activities	Authorities and judicial actors use criteria for CS/digital evidence; improved cooperation between citizens and enforcement bodies; pilots trigger early investigations	FAIR datasets applied in enforcement; evidence admissibility shown in practice; documented success stories of CS supporting enforcement
Step 4 – Scaling & Mainstreaming through the ENFORCE Plaza	Operational ENFORCE Plaza and sub-plazas, Living Labs	High uptake of Plaza resources; active co-creation in Living Labs; increased cross-border collaboration	Demonstrated participation in pilots and Living Labs; consistent tool and data use across sub-plazas; KPIs showing mainstreamed CS in compliance assurance

Partners responsible for developing methodologies and citizen-science activities should read the roadmap as both a conceptual guide and a practical tool for planning their work within the environmental compliance assurance framework. The four steps of the roadmap outline a theory of change that shows how clearer understanding, stronger monitoring systems, more effective enforcement procedures, and sustained institutional learning together lead to improved compliance outcomes. Methodology and citizen-science partners should therefore treat the roadmap as setting out the expectations and conditions that their tools, protocols, and engagement activities must meet. The first step clarifies the legal and governance context, helping partners ensure that citizen-generated information is produced in ways that fit existing environmental rules and evidence standards. The second step defines what counts as reliable, traceable, and usable environmental data, guiding partners in designing citizen-science methods that can be combined with official monitoring approaches. The third step explains how citizen-generated observations must be processed and documented so they can support administrative or judicial action when needed. The fourth step shows how the ENFORCE Plaza creates an ongoing structure for testing, improving, and spreading these methods after initial development. Reading the roadmap across steps helps partners understand the sequence in which their contributions

influence the compliance system, while reading it down through the indicators allows them to connect their activities to measurable outputs, outcomes, and long-term impacts.

Final recommendations

Based on the analysis performed in this report, we can advance the following recommendations:

1. Develop a European and national plan to achieve structural recognition of CS in scientific research processes, as well as in planning, standardization, monitoring and environmental compliance verification processes. To this end, a network of reference centres at European and national level should be established to serve as a point of contact for researchers, legislators, institutions and all stakeholders. The European Commission should develop specific regulations for CS inclusion in compliance assurance.
2. Create funding opportunities at European and national level to strengthen and sustain CS over time and enable capacity and infrastructure development, in order to guarantee not only the necessary initial investments but also, above all, to maintain the management of the organisation and the necessary infrastructure over time.
3. Coordinate the various research projects that use CS in order to enable the sharing and reuse of experiences, methodologies, infrastructure, software and tools, including through a national coordination centre to develop a common vision and proposals for new national CS projects.
4. Include CS in primary school and university educational programmes, promoting the development of interdisciplinary academic courses that explore the use of CS in various fields of research, including specifically training for future legal professionals.
5. Study and improve methodologies and content for data collection, including app prototypes and infrastructure; refine systems for analysing and validating the data collected and solutions for publishing and disseminating the results, both scientifically and for general information purposes, which can also be used to plan the measures needed to maintain environmental compliance over time.
6. Identify and develop means and tools for communication and promotion, including through press campaigns, media and social media coverage, conferences and events, to encourage and maintain the active participation of citizens in CS over time.

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ANNEX I: GUIDES FOR CITIZENS AND PROSECUTORS

Environmental Compliance in Pollution Control (Air, Water, Soil)

Environmental compliance is a living governance process that continually adapts to legal, social, and technological change. Rather than reducing compliance to the enforcement of rules, it is better understood as a dynamic cycle made up of interconnected dimensions: promotion, monitoring, assurance, and evaluation. Each dimension reinforces the others, and all are strengthened by innovation, transparent institutions, and meaningful citizen participation.



Compliance Challenges

Pollution control is challenged by diffuse emission sources, short-term pollution events, and limited inspection capacity. Monitoring networks often lack the spatial density needed to detect localised pollution, creating evidentiary gaps.



Key Legislative & Regulatory Framework in Europe

Key EU instruments include the Industrial Emissions, Landfill, Medium Combustion Plants, Drinking Water, Ambient Air Quality, and Urban Wastewater Treatment Directives, together with the Zero Pollution Action Plan (2021).



Citizen Participation and Innovation

Citizen science can complement institutional monitoring through low-cost sensors and participatory reporting, supporting early detection and compliance when aligned with shared standards and training. Applications such as the Themis app support collecting and delivering environmental evidence.



Guidance for Citizens

Your Rights

- Access pollution-related information
- Participate in consultations
- Report suspected pollution

What You Can Do

- Collect, document observations (date, time, location) and preserve evidence (photos, videos, notes) based on protocols
- Respect legality, privacy, and property rights
- Contribute qualitative observations where needed



Guidance for Prosecutors

Key Legal Thresholds

- Exceedance of binding standards
- Breach of permit or monitoring obligations

Considerations

- Case-by-case assessment and legal compliance
- Interoperability adds value

Evidence needed

- Documentation of methods and chain of custody
- Calibration records or expert validation where relevant

Good practices

- Use citizen data as corroborative evidence
- Apply transparent evidentiary reasoning

The **ENFORCE ECCI TOOL** and **PLAZA** will facilitate structured participation and evidence use in environmental compliance. Learn more: <https://join-enforce.eu/>



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Environmental Compliance in Logging and Forest Governance

Environmental compliance is a living governance process that continually adapts to legal, social, and technological change. Rather than reducing compliance to the enforcement of rules, it is better understood as a dynamic cycle made up of interconnected dimensions: promotion, monitoring, assurance, and evaluation. Each dimension reinforces the others, and all are strengthened by innovation, transparent institutions, and meaningful citizen participation.



Compliance Challenges

Illegal logging persists due to weak institutional capacity, corruption, remote geography, and complex supply chains. Research shows that these factors undermine legality regimes, particularly in parts of Central and Eastern Europe.



Key Legislative & Regulatory Framework in Europe

Key EU instruments include [EU Timber Regulation \(EU\) No 995/2010](#) and [Deforestation-free Products Regulation \(EU\) 2023/1115](#). National forestry legislation is also key,



Citizen Participation and Innovation

Logging is a key area for combining satellite monitoring, digital traceability, and civic reporting. Citizen observations are most effective when aligned with shared methods and interoperable systems.



Guidance for Citizens

Your Rights

- Access forest information
- Report suspected illegal logging

What You Can Do

- Document irregularities with geo-referenced photos
- Preserve the scene
- Follow chain-of-custody procedures
- Collaborate with experts and civil society



Guidance for Prosecutors

Key Legal Thresholds

- Logging without valid permits
- Breach of due diligence obligations

Evidence needed

- Validated species or field data
- Expert corroboration

Considerations

- Case-by-case assessment and legal compliance
- Interoperability adds value

Good practices

- Integrate citizen data into risk-based enforcement

The **ENFORCE ECCI TOOL** and **PLAZA** will facilitate structured participation and evidence use in environmental compliance. Learn more: <https://join-enforce.eu/>



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Environmental Compliance in Biodiversity Conservation

Environmental compliance is a living governance process that continually adapts to legal, social, and technological change. Rather than reducing compliance to the enforcement of rules, it is better understood as a dynamic cycle made up of interconnected dimensions: promotion, monitoring, assurance, and evaluation. Each dimension reinforces the others, and all are strengthened by innovation, transparent institutions, and meaningful citizen participation.



Compliance Challenges

Biodiversity decline persists despite strong legal frameworks, due to cumulative impacts and fragmented enforcement. Law cases confirm the binding nature of EU nature law.



Key Legislative & Regulatory Framework in Europe

Key EU Instruments include Birds and Habitats Directives as well as Nature Restoration Law (2024). National Adaptation Plans play also a key role.



Citizen Participation and Innovation

Citizen science platforms such as MINKA, together with tools like Geo-Wiki and WaCoDiS, support standardised biodiversity monitoring through structured citizen observations and integration with Copernicus and other geospatial data sources.



Guidance for Citizens

Your Rights

- Access biodiversity data
- Participate in conservation planning

What You Can Do

- Record species using validated applications
- Follow standard protocols
- Collaborate with experts



Guidance for Prosecutors

Key Legal Thresholds

- Damage to protected species
- Damage to habitats

Evidence needed

- Validated species data
- Expert corroboration

Considerations

- Case-by-case assessment and legal compliance
- Interoperability adds value

Good practices

- Combine citizen science with expert assessment

The **ENFORCE ECCI TOOL** and **PLAZA** will facilitate structured participation and evidence use in environmental compliance. Learn more: <https://join-enforce.eu/>



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ANNEX II: PERCEPTION SURVEY TEXT

ANNEX III: INTERVIEW TEXT AND ANALYSIS

ANNEX IV: ENOLL SURVEY TEXT AND RESULTS – LEGAL FOCUS



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PERCEPTION SURVEY - Task 2.3

You are invited to fill this **survey** because we believe that your opinion is key to explore actual and perceived barriers that prevent a greater application of **citizen science** for supporting environmental compliance. By **environmental compliance** we intend the various ways in which public authorities promote, monitor and enforce environmental law and policies (find out more [here](#)). Ensuring environmental compliance is essential for protecting natural resources and mitigating the impacts of pollution on ecosystems, and on human and animal health. Citizen science practices can be crucial to support environmental compliance!

With the international project **ENFORCE**, supported by Horizon Europe funding (Grant agreement 101134447), our partnership aims to leverage citizen science and innovative technologies to ensure that locally collected environmental data and information meets the standards and formats required by authorities for promoting environmental compliance. To know more about the project, visit its website at: <https://join-enforce.eu/>

Filling in the questionnaire shall take you indicatively 5-10 minutes.

**Citizen science* refers to activities in which non-professional participants contribute to scientific research including data collection and in some cases data analysis to advance knowledge in the environmental field. Note: in the context of citizen science, the reference to citizenship is synonymous with 'people', including also those who do not hold specific citizenship rights of a certain nation. To know more, you can read [this article](#).



PERCEPTION SURVEY - Task 2.3

1. Do you identify as...? (*just one option possible; if you believe that you represent more than one category, please choose the prevalent one*)

- ☐ Civil society
- ☐ Public authority
- ☐ Academia
- ☐ Legal expert
- ☐ Industry and private sector
- ☐ Other (Please explain)

2. Have you ever worked in the field of environmental compliance (e.g., promoting the respect of environmental laws; detecting environmental crimes etc.) or in fields somehow connected?

- ☐ No
- ☐ Yes (Please explain briefly)

3. Are you familiar with citizen science applied to environmental matters?

- ☐ Yes, very much
- ☐ To a certain degree
- ☐ No

4. Do you believe that citizen science could be used to support compliance with environmental law?

- ☐ Yes, very much
- ☐ Yes, but with limitations
- ☐ No
- ☐ I don't know

5. To what extent do you consider citizen science data and information *reliable* to be used for environmental compliance purposes?

- ☐ Yes, very much
- ☐ Yes, but with limitations
- ☐ No
- ☐ I don't know



PERCEPTION SURVEY - Task 2.3

6. To what extent do you consider citizen science data and information *reliable* to be used for increasing public awareness on environmental matters?

- ☐ Yes, very much
- ☐ Yes, but with limitations
- ☐ No
- ☐ I don't know

7. To what extent do you consider citizen science data to be *complementary* to that gathered by official authorities for environmental compliance?

- ☐ Yes, very much
- ☐ Yes, but with limitations
- ☐ No
- ☐ I don't know

8. Citizen science can be effectively used to bring evidence in court to support environmental compliance. Do you agree?

- ☐ Yes, very much
- ☐ No
- ☐ I don't know

9. Citizen science cannot be mobilised to offer evidence in court but can just be used as an alert to enforcement authorities such as the police. Do you agree?

- ☐ Yes, very much
- ☐ Yes, but with limitations
- ☐ No
- ☐ I don't know

10. What are the main obstacles for using citizen science for environmental compliance?
Rank them from 1 to 5, where 1 is the minor obstacle and 5 is the major obstacle.

	1	2	3	4	5
Legal obstacles such as restrictions to the admissible evidence imposed by national procedural laws	☐	☐	☐	☐	☐
The lack of legal competencies within the citizen science community	☐	☐	☐	☐	☐
The costs of legal aid and of court proceedings	☐	☐	☐	☐	☐
Distrust from lawyers, courts and enforcement authorities towards citizen science	☐	☐	☐	☐	☐
Reluctancy from the same organizations promoting citizen science	☐	☐	☐	☐	☐
The variable quality of data collected through citizen science	☐	☐	☐	☐	☐
Technical hurdles related to the tools used by citizen science	☐	☐	☐	☐	☐



PERCEPTION SURVEY - Task 2.3

11. Can you mention one other barrier that limits the use of citizen science for environmental compliance?

12. Can you mention one opportunity to boost the use of citizen science in environmental compliance?

13. Do you believe that programs offering capacity building on citizen science are needed by law enforcement actors?

- ☐ Yes, very much
- ☐ No
- ☐ I don't know

14. Is there anything that you would like to add? If it is specific to any of the above questions, please refer to it in the free text below (e.g., "With regards to question 7....")

15. Would you be available for a follow-up interview of 1 hour maximum to explore further some of the aspects emerged in this questionnaire?

- ☐ No
- ☐ Yes, you can contact me at:



PERCEPTION SURVEY - Task 2.3

I authorize Associazione A Sud - Ecologia e Cooperazione ODV to process my personal data in accordance with the EU Regulation 2016/79 (GDPR) and the current privacy legislation. See A Sud [privacy policy](#).

Thanks a lot for taking the time to share your opinion and for contributing to building shared knowledge through the ENFORCE project. You can join our online community [here on LinkedIn](#).

WP2 T2.3 Interview Canvas

Introductory words

The international project ENFORCE, supported by Horizon Europe funding (Grant agreement 101134447), aims to leverage citizen science and innovative technologies to ensure that locally collected environmental data and information meets the standards and formats required by authorities for promoting environmental compliance. To know more about the project, visit its website at: <https://join-enforce.eu/>

Note: We assume some degree of familiarity with environmental compliance and with environmental citizen science from the interviewed person (we expect the interviewer to add this information, and to inform us on the function of the person in the interview).

Note: For environmental compliance we intend the various ways in which public authorities promote, monitor and enforce environmental law and policies (find out more [here](#)). Citizen science refers to activities in which non-professional participants contribute to scientific research including data collection and in some cases data analysis to advance knowledge in the environmental field. To know more, you can read [this article](#).

Suggested questions

Do you identify as...?

- Civil society
- Representative of an authority
- Legal expert
- Innovator in the tech sector
- Other (please explain)

Please let us know your affiliation

Please let us know your degree of familiarity with citizen science and with environmental compliance

Do you believe that citizen science could be used to support environmental compliance offering reliable and complementary evidence to official one? If so, how?

Can you share with us any experience of citizen science being used to support environmental compliance, including making reference to actual cases?

Depending on the role of the person, the interviewer select one of the following streams:

- For civil society

In your experience...

Which competencies and resources are missing that limit the effective use of citizen science for environmental compliance? Please list them with examples whenever possible.

Which barriers do you envisage in using citizen science as evidence in court and as an alert to enforcement authorities such as the police? Please list them with examples whenever possible.

- For representatives of an authority

Under which conditions and in which situations would you rely on citizen science for supporting environmental compliance? Please list them with examples when possible.

Which barriers currently limit your institution's ability and/or willingness to rely on citizen science for supporting environmental compliance? Please list them with examples when possible.

- For legal experts

Which procedural and substantive standards would be applicable to citizen science if used to provide evidence in court?

Which procedural and substantive law requirements could pose obstacles to the effective use of citizen science for environmental compliance?

Which legal expertise would be needed for the effective use of citizen science for environmental compliance?

Can you point us to actual cases in which citizen science has been used in judicial settings, if you know any?

For innovators in the tech sector

Which technological barriers do you envisage that limit the possibility to use citizen science for environmental compliance? Please list them with examples when possible.

Which data readiness level would be needed for citizen science to support environmental compliance?

How could we ensure that citizen science data becomes legible and interoperable with official data from enforcement authorities to be used for environmental compliance?

Do you have any questions for us or information to add?

How would you like us to cite you in our study? We prefer only mentioning your role without your name.

Notes - WP2 T2.3 Interview

1. Context

Date:

Place:

Author(s) and partner(s):

Interviewed person:

Their affiliation and country:

WP/Task/Subtask: WP2 - T2.3

2. List of Participants

Name	Organization
...	...

3. Notes

4. Follow-up action (if any)

Data Analysis - WP2 T2.3 Interviews

1. Mark trends according to category **(do not use names / affiliations)**

- Civil society
- Representative of an authority
- Legal expert
- Innovator in the tech sector
- Other (please explain)

2. **AND ALSO** mark trends according to country (e.g., [role if specified, category, country – e.g. volunteer of CS project, civil society, UK])

3. Fill the following fields

Degree of familiarity with citizen science and with environmental compliance of the respondents

Trends related to respondents' beliefs that citizen science can be used to support environmental compliance offering reliable and complementary evidence to official one

Experiences shared by the respondents in terms of citizen science being used to support environmental compliance, including making reference to actual cases

Category-related focuses

- For civil society

Missing competencies and resources reported that limit the effective use of citizen science for environmental compliance. Include examples when cited.

Barriers reported in using citizen science as evidence in court and as an alert to enforcement authorities such as the police. Include examples when cited.

- For representatives of an authority

Conditions and situations under which respondents would rely on citizen science for supporting environmental compliance. Include examples when cited.

Barriers limiting institution's ability and/or willingness to rely on citizen science for supporting environmental compliance. Include examples when cited.

- For legal experts

Reported procedural and substantive standards applicable to citizen science if used to provide evidence in court. Include reference to admissible court evidence in criminal proceedings in the specific countries when reported.

Reported procedural and substantive law requirements which could pose obstacles to the effective use of citizen science for environmental compliance.

Comments on the legal expertise needed for the effective use of citizen science for environmental compliance.

Shared actual cases in which citizen science has been used in judicial settings.

- *For innovators in the tech sector*

Reported technological barriers that limit the possibility to use citizen science for environmental compliance. Include examples when cited.

If mentioned, any consideration related to the data readiness level needed for citizen science to support environmental compliance.

Considerations on how to ensure that citizen science data becomes legible and interoperable with official data from enforcement authorities to be used for environmental compliance.

Any other relevant information added by the respondents

Participant information sheet and Informed consent for participation

1. Title, Project Manager

Dear Participant,

You are invited to take part in the activities of the ENFORCE project, supported by the Horizon Europe programme, coordinated by G.A.C. (France) and promoted in Italy by A Sud Ecologia e Cooperazione Aps. Before deciding whether to participate, it is important that you have all the information you need to make an informed and responsible decision. Please read this document and ask those who proposed this project to you any questions you may have.

2. Brief description and Objectives

The ENFORCE project investigates how **citizen science** and innovative technologies can ensure that locally collected environmental data and information meet the standards required by authorities to promote **compliance with environmental legislation**.

The project aims to bridge the gap between local environmental data and the requirements set by regulatory authorities by promoting collaboration between civil society organisations, researchers, and local administrations and authorities. Through an interdisciplinary approach, ENFORCE is committed to empowering communities to play an active role in environmental governance and enforcement. To learn more about the project, please visit the website: <https://join-enforce.eu/>.

Note: *Citizen science* refers to activities in which non-professional participants contribute to scientific research, including data collection and data analysis to advance environmental knowledge. By *compliance with environmental legislation*, we mean the various ways in which public authorities promote, monitor and enforce environmental laws and policies.

3. What does participation in the study entail?

Participation in the ENFORCE research project involves a 30-minute to 1-hour interview in the agreed language. If useful to the interviewer, and with your consent, the interview may be recorded for note-taking purposes only. The recording will be deleted after transcription. We will process your personal data for the purpose of conducting the interview in accordance with A Sud's [Privacy Policy](#).

4. Benefits, inconveniences and/or potential risks of participation

Participation in the study is voluntary and free of charge. Collaboration does not involve any risk or discomfort for participants.

5. Withdrawal from participation in the project

You have the right to withdraw your consent to participate in this study at any time, even without prior notice or specific reason.

6. Return

You have the right to request information on the results and outcome of the research.

7. Measures envisaged to protect anonymity

The processing of the data collected will be conducted in such a way as to eliminate any reference that might allow individual statements to be linked to a specific person. The results of the research will be published in summary form and in no case will any brief quotations be traceable to individual persons.

8. Contact

Please contact saravegni@asud.net and martalovato@asud.net for further information and clarification you may require regarding this study.

FOR ACCEPTANCE

Place, Date, First Name, Last Name, Signature

ENFORCE – ENoLL Needs Assessment - Living Lab Survey to Assess Common Ground

The upcoming Living Lab survey is designed to evaluate the foundational elements and development stage of various Living Labs. The primary purpose of this survey is to collect insights that will shape the subsequent trainings on Living Lab methodologies, thereby preparing case studies for the creation and operation of Living Labs. The survey will be conducted **online**, and its responses will provide a comprehensive assessment of Living Labs' maturity and areas of focus. By the end of next week (last week of October), the questions for this survey will be finalized. This survey will be integrated with A Sud's legal questionnaire to explore a range of dimensions, offering a well-rounded analysis.

The survey will consist of three key strands:

1. **Living Labs:** Assessing their structure and operational dynamics.
2. **Data:** Exploring how data is managed and utilized within the Labs.
3. **Law:** Examining the legal dimension of each case study (in terms of status, capability and aspiration).

Each responsible partner will contribute their expertise to these strands, ensuring that the survey captures a broad spectrum of information.

Who Should Fill Out This Survey:

Each Living Lab case study should submit one completed survey, which can be filled out collectively by the team. Ideally, the Living Lab representatives should take the lead in filling out the survey to ensure the information provided is accurate and reflective of the Lab's operations.

How: Online questionnaire

When: Survey launches on the week of 11th of November 2024. Deadline to fill out the survey is 22nd of November

By whom: Case studies (1 survey answer per case study)

SECTION 1

By filling in this form and sharing this information you agree to your details being held electronically by the European Network of Living Labs (ENoLL). ENoLL will process your personal data on the legal basis of Art. 6, case b) of GDPR. Your data will be processed in compliance with Regulation (EU) 2016/679 of the European Parliament and of the Council, of 27 April 2016, on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (GDPR) and Law 2018/40581 of 30 of July 2018 on protection of natural persons with regard to the processing of personal data. You can exercise the right of access, rectification, erasure, restriction of processing, portability, and objection, by sending an e-mail to: privacy@enoll.org

1. I agree to share my data with the European Network of Living Labs (ENoLL)

Select one

☐ Yes

☐ No

2. I agree to share my data with partners of the ENFORCE project consortium, for the design and establishment of a common Evaluation Framework, as per GA.

Select one.

☐ Yes

☐ No

SECTION 2

3. Please indicate your Teammates' Names and Surnames.

Open ended question.

4. Please indicate your Teammates' Email addresses.

Open ended question.

5. Please indicate the Name and Country of your Organization.

Open ended question.

6. Please indicate the name of your Case Study.

Open ended question.

7. Which of the following sectors of the quadruple helix does your organization represent?

Multiple answers are possible.

- ☐ Public administration (e.g., city authorities, ministries, ...)
- ☐ Society (e.g., NGOs, community centers...)
- ☐ Private sector (e.g., company, start-up, SME, etc...)
- ☐ Academia (e.g., universities, research centers...)
- ☐ Other (add which)

8. Add a short description of your Case Study focus (i.e., what you are working on, your goals, your main challenges, etc.) If you have a webpage, please add the link here as well.

Open ended question.

9. In which sectors is your Case Study/Organization active?

Multiple answers are possible.

- a) Agriculture and Agri-food
- b) Circular economy Culture, creativity, and media
- c) Education and/or vocational training
- d) Emerging technologies (e.g. AI, AI/VR...)
- e) Energy Environment and climate change
- f) Health and Wellbeing
- g) Industries and Manufacturing
- h) Mobility
- i) Policies
- j) Regulatory learning
- k) Rural
- l) Smart cities and regions
- m) SME and start-ups
- n) Social innovation and inclusion
- o) Urban Water (blue economy)
- p) Zero pollution and decarbonization

- q) Other (explain)
- r) I don't know

SECTION 3

10. On a scale from 1 to 5, how do you consider yourself familiar with the Living Lab concept and methodology?

Open ended question.

1=no familiarity - 5=high familiarity

ENoLL defines Living Labs as "open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities, placing citizens at the centre of innovation. Living Labs operate as intermediaries among citizens, research organisations, companies, and government agencies for joint-value co-creation, rapid prototyping or to scale up innovation and businesses. Living Labs use iterative feedback processes throughout the lifecycle approach of an innovation. "

11. Are you already a Living Lab or do you already host one?

Select one

- ☐ Yes
- ☐ No
- ☐ Partially
- ☐ I don't know

12. Have you previously worked on a project where you had to develop a Living Lab or use the Living Lab methodology?

Select one

- ☐ Yes
- ☐ No
- ☐ Partially
- ☐ I don't know

13. Do you consider your Case Study as a Living Lab yet?

Select one

- ☐ Yes
- ☐ No
- ☐ Partially
- ☐ I don't know

14. On a scale from 1 to 5, indicate how strongly you agree with the following:

1=no familiarity - 5=high familiarity

- a) Our Case-study (CS) core team has a clear vision for our LL.
- b) Our CS core team has the adequate skillsets to run our LL.
- c) Our CS core team feels ownership over our LL and its future.
- d) Our CS core team understands what a LL is.

- e) Our CS core team can confidently explain the LL concept to non-experts.
- f) Our CS core team has a clear plan for our next steps.
- g) Our CS core team has a clear overview of the stakeholders to include.

15. Do you feel your team has the necessary resources (financial, technical or otherwise) for your LL to be successful?

Open ended question.

16. Please tell us more about the current state of your Case Study.

Open ended question. Use the following questions as a guideline.

Are you established as a legal entity? (yes, no, in the process, I don't know)

Have you identified any partners? (yes, no, in the process, I don't know)

Have you identified any stakeholders you will engage? (yes, no, in the process, I don't know)

Have you defined the technical project you will be working on? (yes, no, in the process, I don't know)

17. Have you already established an approach to monitor and evaluate the performance of your CS?

Select one

☐ Yes

☐ No

☐ Not yet, but planned to

☐ I don't know

18. Which Living Labs topics are you most interested in learning more about?

Multiple answers are possible.

- a) Living Lab basics principles & concepts (LL definition, what is a LL and what is not, key steps to set up a LL)
- b) Stakeholder Engagement Methodologies & Tools
- c) Governance Models for Living Labs
- d) Business Models and Funding Opportunities for Living Labs (how to ensure LL sustainability over time)
- e) IPRs of Living Labs
- f) Experimentation and Co-creation strategies
- g) Strategic Communication of Value and Activities of Living Labs
- h) Participatory process and user engagement
- i) Regulatory & Legal
- j) Citizen centered co-creation methods
- k) Financial (e.g. fundings opportunities and strategies)
- l) Monitoring (assessment tools, impact assessment KPIs, annual control and reporting)
- m) Other (suggest other topics of your interest here)

19. What are the main barriers in setting up/deploying your successful Living Lab, considering your specific context and environment?

Open ended question.

20. What are your CS's key strengths or areas of expertise?

Open ended question.

SECTION 4 - LEGAL FOCUS

- Do you have the capacity to identify legislation and existing legal cases relevant for your case study?

Yes, I can rely on this capacity within my organization

Yes, I can rely on professionals within my network

No

-If you answered yes, this capacity relates to *(Multiple option possible):*

Local legislation

National legislation

EU legislation

Criminal law

Administrative law

Civil law

I don't know

- Have you already performed a mapping effort to identify and collect legislation and existing legal cases relevant for your case study?

Yes

No

If you answered yes, whenever possible please share any useful database, xls or folder

- Is there any legal action or extra judicial action related to your case study?

Yes, ongoing

Yes, planned

Yes, concluded

No there is none

I don't know

- Would you be inclined to enable a legal and/or extra judicial action through your case study?

Yes, including by enabling the initiation of a potential court case by doing preparatory work

Yes, but only for extra judicial actions (like alerts to police and mediation processes)

Yes, both options

No

- Is your case study facing barriers in relation to applicable legislation and/or from a procedural perspective?

Yes

No

I do not know

If you answered yes, please list the main barriers that you identified by bullet points:

(free field, for example you can indicate the difficulties in understanding applicable legislation or the presence of conflicting legislation, limits of some procedures or courts)

SECTION 5

The following list presents the technologies that will be further developed in the ENFORCE project.

i) please indicate your level of experience with each of the following data tools and platforms (1-5¹)

ii) would one or more of the tools bring value to your case study specific activities?

- a) Visualizing & analyzing environmental surveillance information (UNEXE)
- b) Environmental forensics analysis (UNEXE)
- c) Geo-Wiki Toolbox for Citizen Science (IIASA)
- d) Data Space Compliance platform (SLG)
- e) WaCoDiS Platform (52N)
- f) MINKA Citizen Observatory (CSIC)
- g) Early warning smartphone application (Themis App) (UoC)
- h) Geoinformation within CS areas (open-source platform) (HB)
- i) River Health-focused Citizen Science tool (WRT)
- j) Urban Ecology Field Atlas (Waag)

"Are there existing policies or regulations on environmental compliance that could impact the planning or content of the living lab in this area?"

- Yes
- No
- Not Sure

If "Yes," please specify any potential challenges or opportunities they may present.

¹ 1= I have no experience/knowledge of the tool, 2= I have heard of the tool/platform, 3= I am familiar with the tool functionalities, 4= An external case study stakeholder is an active user, 5= The tool is part of our case study activities

CSs knowledge about Law													
Case Study Number	Do you have the capacity to identify legislation and existing legal cases relevant for your case study?	If you answered "Yes" this capacity relates to: Local legislation	If you answered "Yes" this capacity relates to: National legislation	If you answered "Yes" this capacity relates to: EU legislation	If you answered "Yes" this capacity relates to: Civil law	If you answered "Yes" this capacity relates to: Administrative law	If you answered "Yes" this capacity relates to: Criminal law	If you answered "Yes" this capacity relates to: I don't know	Have you already performed a mapping effort to identify and collect legislation and existing legal cases relevant for your case study?	Is there any legal or extra judicial action related to your case study? Include any useful existing links in the section "Other"	Would you be inclined to enable a legal and/or extra judicial action through your case study?	Is your case study facing barriers in relation to applicable legislation and/or from a procedural perspective?	If you answered yes, please list the main barriers that you identified by bullet points. Free field; for example, you can indicate the difficulties in understanding applicable legislation or the p...
CS#1	Yes, I can rely on this capacity within my organization.	X	X	X	X	X			Yes	Ongoing and concluded.	Yes, both options.	Yes	Limits of administrative courts often in charge of cases related to the implementation of environmental laws: but they have often unsuccessful outcomes, in general legal action has a time and cost which refrain actions from civil society, once provided that citizens are not mistrusting legal action
CS#2	Yes, I can rely on this capacity within my organization.	X	X	X		X			No	No.	No.	No	n/a
CS#3	Yes, I can rely on professionals within my network.		X	X	X	X	X		Yes	Yes, planned.	No.	I do not know	Difficulties with proving the liability of an operator or perpetrator; Limited responsibility of corporate persons/administrative bodies; Lack of effective and uniform application; Lack of expertise (no special environmental police / environmental courts).
CS#4	Yes, I can rely on this capacity	X	X	X					For the descriptors, we focus on	It is just the follow up of the	No.	No	n/a

	within my organization.								legislative compliance with the MSFD Marine Strategy: D1- Biodiversity, D8- Pollutants, D10 Marine litter	environmental compliance of the MSDF			
CS#5	Yes, I can rely on professionals within my network.	X	X						No	I do not know.	No.	I do not know	n/a
CS#6	Yes, I can rely on professionals within my network.							X	No	I do not know.	Yes, but only for extra judicial actions (like alerts to police and mediation processes).	I do not know	I don't know
CS#7	Yes, I can rely on professionals within my network.	X	X	X					Yes	Yes, ongoing.	Yes, both options.	Yes	Legislation not clear, different interpretation of the law, few precedents, pro-farmer sentiment
CS#8	Yes, I can rely on professionals within my network.	X	X	X		X			Yes, but nothing concrete to show yet.	Yes, planned.	Yes, both options.	Yes	The main takeaway is that PFAS legislation is almost non-existent and limited to an ECHA PFAS restriction proposal. Furthermore, it is quite fragmented between EU countries.