UNIVERSITÀ DI PARMA

UNIVERSITÀ DEGLI STUDI DI PARMA

DOTTORATO DI RICERCA IN
"*Ingegneria Industriale*"

CICLO XXXVIII

The Role of Plant-Based By-Products in the Circular and Green Transition: Regulatory Challenges for Industrial Symbiosis in the Agri-Food Industry

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Anni Accademici 2022/2023– 2024/2025

Funder: Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 1 Investment 3.4 and 4.1 - Call for tender No. 351 of 09/04/2022 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU

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Introduction:

As Popper stated[1] , progress arises from questioning existing paradigms. As the prevailing paradigm pushes humanity to the edge of irreversibility, scientific research becomes fundamental for driving urgent and necessary progress.

The complex transition period in which humanity is both victim and perpetrator calls for all scientific knowledge to develop viable solutions that serve the instinct for self-preservation.

The search for solutions presupposes the existence of problems. Etymologically, the term "problem" derives from the Greek verb προβάλλω (literally: to put in front). A problem is an obstacle placed on a path. Every obstacle can be removed through a solution (a term derived from the Latin *solvere;* literally: to dissolve). From this, it is possible to understand the most authentic meaning of the concept of academic research: finding solutions capable of eliminating existing obstacles.

Nowadays, every solution is multifaceted since the challenges associated with the real world's complexity affect different but interdependent areas simultaneously. This justifies the author's decision to carry out her doctoral research, which was linked to purely legal issues, in an engineering context.

This research aims to propose micro-solutions in a context of macro-problems, considering interdisciplinarity and transversality as the cornerstones of the investigation.

The research question revolves around the need to recalibrate the existing legal paradigm to fully affirm models of industrial circularity and ecocentrism, emphasising how human activities can still take on connotations of ecocentrism.

[1] K.R. POPPER, *La ricerca non ha fine: autobiografia intellettuale,* Armando Editore, Roma, 1978.

This aspect aligns with Mancuse's view that contemporary society is inhabited by «one-dimensional men»[2], who are passively addicted to patterns of thought that are far from a balance of values, and who are incapable of guiding change.

In this sense, the challenge for every jurist is to resist the temptation to rely on a single dimension, seeking three-dimensional profiles even in the regulation of sectors that, at first glance, have little to do with the cornerstones of contemporary legal principles.

In the author's opinion, this three-dimensionality implies a change in perspective, as well as a departure from the traditional conception of legal practitioners. This requires the jurist to strike a complex balance, engaging in dialogue with science without replacing the scientist and synthesising disparate languages, methods and purposes within the confines of a shared rationality.

This paper takes on the challenge of giving a legal voice to an issue that falls within the remit of industrial circularity: the valorisation of plant-based by-products within the agri-food sector. At first glance, this topic may seem legally uninteresting and unsuitable for exploring solutions that go beyond green chemistry, industrial plant engineering and business logistics.

On the contrary, this paper aims to demonstrate the complex legal issues underlying the reuse of fruit peel (or any plant residue) in an industrial ecosystem, and to propose new perspectives that the institutional world can implement.

Plant by-products, in fact, hold significant potential in the European bioeconomy. Their possible exploitation as ingredients in food, biomaterials, soil improvers (etc.) is a significant booster of sustainability, which, at times, is discouraged by an overly uncertain and obstructive legal framework about a single market for renewable resources.

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[2] H. MARCUSE, *One-Dimensional Man: Studies in the Ideology of Advanced Industrial Society,* Beacon Press, Boston, 1991.

Considering the need to reconsider the legal instruments associated with circular processes, the regulation of plant by-products provides an opportunity to develop proactive legislation aimed at sustainable development, facilitating the creation of practical and tangible outcomes. In this specific case, the category of plant by-products has been addressed from two perspectives: on the one hand, to clarify interpretative and regulatory uncertainties, and on the other, to identify regulatory strategies and governance models to integrate environmental, economic, and social needs.

From a methodological perspective, this was achieved by taking a multi-level, interdisciplinary approach that combined legal and systematic analyses, profiles of the integration of food law into environmental law, and considerations of the part played by empirical legal research in European circular economy policies. The One Health paradigm and an evidence-based perspective are the common threads running through the entire discussion.

The thesis is structured in four parts, organised around a concentric circle model of investigation. Rather than addressing the issue of plant residues immediately, the author focuses on defining contextual challenges and multi-level legal perspectives.

The first chapter introduces the theoretical framework of complexity and the role of law in transitions in a polycrisis era, highlighting the value of circularity in the context of industrial symbiosis as a possible response.

The second chapter is focused on the European and national regulatory framework on waste, end-of-waste and by-products, offering comparative insights. It highlights critical regulatory issues taking into consideration an analysis of regulatory texts, European case law, and various legal systems. Furthermore, it examines possible strategies for implementing and promoting a single market for by-products. In this context, it is important to note that the aim is not only to identify potential new legal solutions, but also to reinterpret existing legal institutions in the context of a more circular economy (e.g. IPCEI, certifications, procurement, etc.).

The third chapter forms the core of the discussion, as it explores the topic of by-products in the agri-food sector, with a particular focus on those of plant origin. This has been developed with the understanding that, while plant-based by-products from the food industry share the same basic issues as any other by-product, their food dimension adds a degree of complexity, as they are subject to critical operational issues linked to the circular food economy (e.g, food upcycling and novel foods).

The fourth and final chapter sets out the basis for adopting an empirical approach to assessing the regulatory effectiveness of the by-product institution in the agri-food sector.

Overall, therefore, the paper aims to present this legal institution and focus on its dynamic role in connecting systems, highlighting its ability to effect real change in production patterns and the public policies underlying them.

Chapter 1: Law, Complexity and Circularity: Governing Transitions in the Age of Polycrisis

1.1 The Starting Point of Polycrisis Complexity. General Premises

The most urgent challenges of our time do not occur in isolation but appear as interconnected and layered phenomena. Understanding them requires an approach capable of grasping their complexity and the nature of a polycrisis. As Edgar Morin writes, «complexity cannot be reduced to simplification, but must be thought of in its intertwined nature»[3] .

If, on one hand, complexity[4] represents systems characterized by interconnected elements, on the other hand, polycrisis[5] highlights the simultaneity

[3] E. MORIN, *La Méthode. 1: La Nature de la Nature,* Paris, Points Essais, 1977.

[4] On the issue of complexity, see E. MORIN, *Introduction à la pensée complexe, Paris,* Points Essais, 2014. On this point, the French philosopher and sociologist developed a theory of complexity that critiques reductionist thinking and proposes a systemic and interdisciplinary approach. In his view, reality is characterized by interconnections, feedback loops, and non-linearity, making it impossible to fully understand it through separate and fragmented analyses. On the level of hard sciences and the multidisciplinary nature of the environmental issue, see F. CAPRA, *The Turning Point: Science, Society, and Emerging Culture,* Feltrinelli, Milan, 2013.

[5] Polycrisis is a situation in which multiple crises occur simultaneously, interacting with and exacerbating each other. These crises can span economic, political, environmental, health, or social domains, creating a systemic effect that makes management and resolution particularly complex. The term highlights how global challenges are interconnected rather than isolated, requiring coordinated and multidisciplinary responses. This was coined in the context of the study of the philosophy of complexity. On this point, see E. MORIN, A.B. KERN, *Homeland Earth: a Manifesto for the New Millennium,* Hampton Press, New York, 1999. The term polycrisis has been widely used by the World Economic Forum (WEF) to describe the convergence and interconnectedness of global crises that reinforce each other, creating unprecedented complexity. In

of multiple crises (e.g., climate, economic, political) which, by reinforcing each other, aggravate global instability. Each individual crisis does not occur in isolation but causes systemic effects that are very difficult to manage.

Today, *polycrisis* is the main feature of the system we live in. In a field of study where philosophy and mathematics intersect[6] , there is a recurring formula:

$$S = \sum_{i=1}^{n} P_i + E$$

This equation illustrates the principle that the interaction of a system's parts produces a result that is more complex than the mere sum of those parts: the symbol "S" represents the entire system, "Pi" denotes its individual components. The term "E" refers to the so-called "emergent properties", meaning all elements that arise due to the interaction of the systemic parts.

Every complex system produces a systemic surplus, and the phenomenon is greatly amplified when we consider that we are accustomed to identifying different systems in our reality[7] - such as the economic, sociological, and legal systems- interacting with each other.

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the Global Risks Report 2023, the WEF highlighted how simultaneous events, such as climate change, geopolitical instability, economic crises, and social tensions, can no longer be analyzed separately but must be understood as an interconnected system. This perspective aligns with Edgar Morin's complexity thinking, emphasizing the need for systemic and collaborative approaches to tackle global challenges. World Economic Forum *Global Risks Report 2023* <www.weforum.org/publications/global-risks-report-2023/ > accessed January 31, 2025. See also A. TOOZE, *Crashed: How a Decade of Financial Crises Changed the World,* New York, Viking, 2018.

[6] On this point see L. MARI, *Qualche riflessione sulla retroazione come caratteristica sistemica* in *Rivista di Filosofia Neo-Scolastica* 4, 2011, pp. 571 ff.

[7] Italian legal doctrine applies Luhmann's theory to analyze interactions between systems with different semantics. Please refer to F. FRACCHIA, *Transizioni: il punto di vista del diritto*

For example, an overly strict environmental regulation might not be accepted by private economic operators who, contrary to the regulation's primary goal, opt to relocate their activities to countries with lower ecological standards. Additionally, consider how a banking disaster can cause private citizens to develop complete distrust of public institutions: this situation is connected to a significant decrease in democratic participation, which encourages the rise of populism and political and economic instability.

These aspects tend to develop in societies overly committed to the paradigm of simplification that Edgar Morin[8] attributes to the principles of disjunction,

amministrativo, Napoli, Editoriale Scientifica, 2024. In this regard, for a basic understanding of Luhmann's theory, reference is made to N. LUHMANN, *Rechtssoziologie 1,* Studium RoRORO, 1972. Based on autopoietic systems thinking, Luhmann's theory conceives of society as a set of functionally differentiated subsystems, such as law, politics, economics, and science. Each of these subsystems is governed by its own binary code (e.g., lawful/illegal for law and true/false for science). These systems are operationally closed in that they operate autonomously, yet cognitively open in that they are able to observe and respond to stimuli from their context. Through structural couplings, systems can form relationships without losing their internal coherence, thereby activating complex forms of coordination and mutual "irritation".

[8] See, E. MORIN *Introduction à la pensée complexe, op. cit., p*. 18 «Nous vivons sous l'empire des principes de disjunction, de reduction et d'abstraction don't l'ensamble constiue ce que j'appelle le "paradigme de simplification" […] une telle disjunction, raréfiant les communications entre la coinnaissance scientifique et la réflexion philosophique, devait finalement priver la science de toute possibilité de se connaître, de se réfléchir, et même de se coincevoir scientifiquement elle-même. Plus encore, le principe de disjunction a isolé radicalement les uns des autres les trois grands champs de la connaissance scientifique: la physique, la biologie, la science de l'homme. La seule façon de remédier à cette disjonction fut une autre simplification: la réduction du complexe au simple […]. Une telle connaissance fondait nécessairement sa rigeur et son opérationnalité sur la mesur et la calcul; mais, de plus en plus, la mathématisation et la formalisation ont désintégré les êtres et les existants pour ne considérer comme seules réalités quel es formules et équations gouvernante les entités quantifiées. Enfin, la pensée simplifiante est incapable de concevoir la conjonction de l'un et du multiple. Ou bien, elle unifie abstraitement en annullant la diversité. Ou, au contraire, elle juxtapose la diversité sans concevoir l'unité. Ainsi, on arrive à l'intelligence

reduction, and abstraction, and which Bruno Latour[9] describes as too dichotomous and too little interconnected. Understanding complexity must be based on an in-depth analysis of connections, flows, and feedback. This is necessary for tackling multiple crises.

It is no coincidence that the term crisis (from the Greek κρίσις) derives from the Greek verb "κρίνειν", which means to separate, judge, and decide. In ancient Greece, "κρίσις" represented a decisive stage in a process that would lead to an irreversible change[10] .

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auvegle. L'intelligence auvegle, détruit les ensambles et les totalités, elle isole tout ses objets de leur environnement».

[9] B. LATOUR, *Nous n'avons jamais été modernes,* La Découverte, Paris, 2006. In this book, Latour argues that the modern era's claim to separate nature from society, science from politics, objects from subjects, is a myth. We constantly create hybrids: entangled networks of humans and non-humans, ideas and technologies. By exposing this contradiction, Latour invites us to rethink modernity and offers the foundation for what would become Actor-Network Theory (ANT), a new approach to understanding how knowledge and power circulate through complex, interconnected systems.

[10] The term krisis (κρίσις) was linked to a decisive moment in several contexts. In the medical field (think of Hippocrates) it related to a turning point in an illness, when the sick person was either destined to recover or succumb. It is no coincidence that in the Aphorisms we read, «Καὶ τῶν νόσων αἱ κρίσεις γίνονται κατά τὰς ἡμέρας ταύτας» (And in diseases crises occur on certain days) (II, 21). In the historical-political sphere, the historian Herodotus makes the term krisis his own to describe turning points that change the course of events. Consider, for example, Xerxes' decision to cross the Hellespont and invade Greece (Histories, VII, 5-10). In tragedy, the notion of krisis is central to dramatic structure. In works such as Sophocles' Antigone, the conflict between the laws of the city and divine laws results in an irreconcilable collision: the clash between Antigone and Creon represents its critical moment. In philosophy, the term takes on a meaning ascribable to the ethical realm. Plato, in the Gorgias, lets Socrates state, «ἡ κρίσις τῆς ψυχῆς ἐστὶ τὸ μέγιστον πρᾶγμα» (The judgment of the soul is the greatest thing) (526d). True crisis, then, also relates to the value of psychological choices. With Aristotle, finally, krisis is linked to rational judgment, cosubstantiating in the Rhetoric that each political and ethical decision requires is always the result of a critical act of discernment.

The concept of crisis has also been a subject of study in contemporary philosophy, which has attempted to theorize its scientific features[11] , which have been identified in the autonomization of processes, the periodicity/cyclicality of phenomena, and globalization [12] .

The πολύκρισις, therefore, is inextricably linked to the breakdown of a balance, which is followed by a moment of transition. From this, it is possible to understand why transition is defined as a «*category widely used to interpret (or describe) certain contemporary problems*»[13] to develop a common denominator[14]

[11] For an in-depth analysis see PAUL RICŒUR, *La crise: un phénomène spécifiquement moderne?, Revue de Théologie et de Philosophie,* 1, 1988, pp. 1 ff. The A. reflects on the nature of *crisis* and questions whether it is truly a phenomenon unique to modernity. He begins by tracing the historical origins of the term, which comes from medical and judicial contexts—referring to a decisive moment, a turning point. Over time, however, the concept has taken on broader cultural, political, and philosophical meanings. Ricœur explores how modern societies often view themselves through the lens of crisis—whether it's a crisis of values, identity, authority, or tradition. He argues that this tendency is not necessarily evidence of actual collapse but rather reveals a particular way modernity understands itself: as being in constant transition and self-questioning. For Ricœur, the language of crisis is central to modern consciousness. It reflects a tension between preserving the past and embracing change. While crises may seem destabilizing, they also open space for rethinking, reevaluating, and reshaping institutions and ideas. In the end, Ricœur suggests that although crises have occurred throughout history, modernity distinguishes itself by how it interprets and responds to them—seeing crisis not just as danger, but as an opportunity for transformation.

[12] With focus on the theme of globalization, see H. KISSINGER, *Ordine globale,* Mondadori, Milan, 2017.

[13] F. FRACCHIA, *Transizioni: il punto di vista del diritto amministrativo,* Editoriale Scientifica, Napoli, 2024.

[14] *Ibidem.*

for a whole series of problems belonging to a "risk" and "liquid"[15] society[16]. Contemporary society is called upon to address a number of transitions: for example, those relating to energy, ecology, food, digital technology, urbanization, work, and demographics. The enormity of the current polycrisis has, in fact, led to a veritable "systemic transition".

In other words, the unsustainable actuality must be followed by a redefinition of the dynamics of reality, through the adoption of a suitable method (from the Greek μέθοδος, literally "way to follow").

Each method is shaped by a political-epistemological filter that determines the criteria through which we interpret surrounding complexity, while simultaneously questioning both the boundaries and the transformative potential of knowledge.

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[15] Z. BAUMANN, *Modernità liquida,* Bari, Laterza, 2011. In the context of systemic transition, Bauman's insights help us understand the resistance to change, identity crises, and the need for new points of reference that emerge in societies experiencing multiple simultaneous dislocations. See also, ID. *Retropia,* Bari, Laterza, 2017.

[16] U. BECK, *La società del rischio: verso una seconda modernità,* Roma, Carocci Editore, 2013. The Author puts forward an original sociological analysis of contemporary societies, which are characterized by the production and distribution of global risks that cannot be managed through the institutional structures and conceptual categories of industrial modernity. He introduces the concept of 'second modernity' to describe an era in which the dangers produced by development itself, such as climate change, financial crises, and nuclear disasters, become central and structural. According to his theory, these risks are interconnected, invisible, irreversible, and transnational, and require new models of governance, knowledge, and responsibility. In this sense, Beck's work is closely linked to the concepts of systemic complexity and polycrisis, as it emphasizes the inadequacy of modern paradigms in dealing with interdependent and unpredictable phenomena. The risk society thus becomes a laboratory for exploring new forms of rationality based on precaution, global cooperation, and an awareness of uncertainty.

1.2 The Role of Law in Governing Transitions

When it was stated that *«every science finds in its own nature and in its own procedures some particular and specific cause of* error[17] *»,* it was emphasized how complexity contributes to highlighting the structural limits of every science.

No single discipline can, on its own, resolve the systemic and interdependent problems that characterize contemporary reality. Hence, an authentic interdisciplinary dialogue is required, where the epistemological tools of science, economics, and law intersect and cooperate in pursuit of coherent and mutually reinforcing results. In this context, consider the need for interaction between law, science, and technology (a direct result of science)[18] .

These aspects are explored in depth in a well-known legal-philosophical debate[19] , according to which: law derives from political impulses and develops to pursue certain objectives; technology is not linked to any specific purpose, but to the need to produce results.

In other words, the outcomes of their interaction vary according to the way in which the law integrates and frames technical solutions within the broader

[17] Reference is made to S. ROMANO, *Lo stato moderno e la sua crisi,* Pisa, Tipografia Vannucchi, 1909, p.1.

[18] With a particular focus on the evolution of law in the innovation era, reference is made to A. FARÌ, *Ambiente e innovazione. Una prospettiva giuridica,* in *RQDA*, 4, 2020, pp. 92 ff.

[19] On this point, see N. IRTI, E. SEVERINO, *Dialogo su diritto e tecnica,* Editori Laterza, Bari, 2001. The two philosophers engage in a philosophical and legal exchange about the transformation of law in the age dominated by technology. Irti, a legal positivist, views technology as a force that dissolves the certainties of traditional law and undermines any claim to absolute foundations within the legal system. Severino, a philosopher of destiny and critic of Western nihilism, interprets technology as the ultimate expression of the West's will to power. Despite their differing perspectives, the dialogue reveals the deep crisis of modern law, now confronted not with transcendental values or moral imperatives, but with the autonomous and impersonal logic of technology.

strategic design to be pursued. These consequences are linked to many variables, from the possibility of identifying science and technology as mere instruments of economic profit, to that of including them in an ethical-legal dimension where the objective of maximizing efficiency is balanced with the needs of protecting life and safeguarding the human future.

In this regard, it should be noted that, according to Hans Jonas[20] , technology can be a blind force if it is not oriented towards a teleology that safeguards environmental, social, and anthropological dimensions.

In this sense, this general framework aims to emphasize how law, understood as the main driver of all public policy, must increasingly be considered a transformative and proactive matrix of technical and scientific change in an ethical and sustainable direction[21] .

In this regard, there are several difficulties. The first depends on the difficulty of the law in translating heterogeneous knowledge into legally relevant, accurate, and effective data (through processes of abstraction, simplification, and reinterpretation).

Furthermore, the law has traditionally aimed to create stable categories (general and abstract) that do not always match the frenetic dynamism of constantly evolving scientific knowledge. In other words, the role of legal mediation leads its

[20] See, H. JONAS, *Das Prinzip Verantwortung,* Insel Verlag, Frankfurt, 1979. The Author argues for a new form of moral responsibility that is suited to the unprecedented power of modern technology. Moving beyond traditional anthropocentric and short-term ethical models, he advocates a forward-looking ethic that prioritizes protecting future human life and the natural environment. His ideas have significantly influenced debates concerning bioethics, environmental law, and the regulation of technological innovation.

[21] For further insights into the notion of transformative law, see B. BOSCHETTI, *Diritto e resilienza (trasformativa). Coordinate per un diritto resiliente capace di transizioni,* in *Forum di Quaderni Costituzionali,* 3, 2023, pp. 209 ff. See also, G. TEUBNER, *How the Law Thinks: Toward a Constructivist Epistemology of Law,* in *Law & Society Review,* 5, 1989, pp. 727 ff.

operators to translate the language of the hard sciences or, for example, that of economics into binding prescriptions.

However, this can take place by following a three-way path where the law defines an insurmountable perimeter based on principles, interacts *ex ante* with science in defining objectives, and ensures that technology operates in accordance with economic, social, and ecological goals.

Considering these methodological premises, the role of law emerges not merely as a regulatory instrument, but as a driving and enabling force for transition processes. Within this perspective, the following analysis focuses on the need to place environmental objectives at the very core of public policy.

1.3 Environmental and Circular Governance in Public Policy

American political scientist David Easton stated that «public policy [...] consists of a network of decisions and actions that allocate values»[22]. As is often the case, it is precisely these brief and precise definitions that are most incisive, as they offer perspectives for analysis and reasoning that are useful for navigating the complexity of the current "polycrisis"[23].

This definition allows us to draw several initial insights. First, public institutions in any democratic system – at various levels – are required to establish a network of decisions and actions to find solutions to problems of common interest. In our era, solutions to issues of common interest are characterised by transversality, as dialogue between different disciplinary sectors is the only effective way to implement forward-looking and efficient public interventions.

[22] D. EASTON, *The Political System: An Inquiry into the State of Political Science,* New York, Knopf, 1953, p. 130.

[23] With reference to the literature on the subject, please refer to note n.5

If we compare public policy to a technological tool, we can say that it also relies on binary logic, where *bits* and *bytes* are replaced by the "tool-objective" pairing. And it is precisely within this binary "tool-objective" framework that public authorities reframe themselves as interlocutors of the private sector and potential protagonists in the internalisation of common interests in market dynamics.

Within this framework, the legal aspect plays a fundamental role because it is through the law that public strategies and policies[24] are enforced and made binding. While recognising the critical nature of the legal instrument during transitions, it operates to institutionalise sustainability, translating the demands of the significant policy frameworks of the United Nations and the European Union into binding rules and higher-level principles.

It follows that law, besides being an "instrument" for implementing public policies (the previous section refers to it as a catalyst for objectives), becomes itself an «objective» of transformation, as it is called upon to renew itself through innovative categories. The law, therefore, is not only an instrument of implementation but also an objective in itself. Its structure and principles must evolve so that the legal system does not remain anchored to anachronistic logic but can promote institutional, economical[25], and cultural innovation.

In this context, environmental law serves as a key testing ground for the capacity of law to manage complexity. It is no coincidence that legal doctrine defines it as a "probing law"[26], precisely because it features innovative elements

[24] The topic of public policy with a particular focus on the environment is extensively covered in P. COLETTI, *Le politiche ambientali,* Bologna, Il Mulino, 2024.

[25] On the impossibility of studying law without considering economics, see G.D. ROMAGNOSI, *Dalla necessità di unire lo studio della politica economica con quella della civile gurisprudenza,* in *Annali Universali di Statistica*, vol. XXXIII, 1932.

[26] On this point, see F. SPANTIGATI, *Le categorie necessarie per lo studio del diritto dell'ambiente,* in *Rivista Giuridica dell'Ambiente*, 2, 1999, pp. 221 ff.

that allow it to explore and anticipate new solutions that are hopefully suitable for positively governing all the transition processes and involving the environment and its related issues[27]. From its original defensive role, environmental law is called upon to adopt a proactive approach where multidisciplinarity, transversality, complexity, and dialogue are more effectively integrated. From its initial repressive dimension, it is necessary to refine the incentive dimension of solutions compatible with the ecological limits of the planet[28].

This forms part of the primary, global aim to put the principle of sustainable development[29] into practice, preventing current and future generations from reaching a point of no return.

Indeed, the current phase is characterised by the threat of irreversible ecological collapse, underscoring the urgency of producing timely and effective outcomes to avert irreparable harm in the near future.

The basket of problems of common interest is overflowing[30]: climate collapse, excessive exploitation of the planet's resources, and the uncontrollable

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[27] On this point, see F. DE LEONARDIS, *La transizione ecologica come modello di sviluppo di sistema: spunti sul ruolo delle amministrazioni,* in *Diritto Amministrativo,* 4, 2021, pp. 779 ff.

[28] See F. DE LEONARDIS, *Lo Stato ecologico, op. cit.,* p. XX.

[29] Regarding sustainable development, the well-known definition provided in the 1987 Brundtland Report recognized it as «development that meets the needs. of the present without compromising the ability of future generations to meet their own needs.»; see, WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, *Our Common Future*, Oxford Paperbacks, 1990. At the doctrinal level, *ex multis,* see E. TIEZZI, N. MARCHETTINI, *Che cos'è lo sviluppo sostenibile?* Donzelli Editore, Roma, 1999; G. GUIDO, S. MASSARI, *Lo sviluppo sostenibile. Ambiente, risorse, innovazione, qualità. Scritti in memoria di Michela Specchiarello,* Franco Angeli, Milano, 2013; J.D. SACHS, *The Age of Sustainable Development,* Columbia University Press, 2014; F. FRACCHIA, *Lo sviluppo sostenibile. La voce flebile dell'altro tra protezione dell'ambiente e tutela della specie umana,* Editoriale Scientifica, Napoli, 2010.

[30] For an in-depth analysis, reference is made to W. STEFFEN et al., *Sustainability. Planetary Boundaries: Guiding Human Development on a Changing Planet*, Vol. 347, Issue 6223, 2015. See also, B. MCBAIN et al., *How Long Can Global Ecological Overshoot Last?,* in *Global and Planetary*

increase in overpopulation are just some of the contributing factors that need to be addressed from a multi-level perspective and with intergenerational responsibility[31].

If, on a global scale, Agenda 2030[32] assigns public authorities the responsibility of turning the three-dimensional concept of sustainability «leaving

Change, Vol. 155, 2017, pp. 13 ff.; E.H. VAN NES et al., *What Do You Mean, 'Tipping Point'?, in Trends in Ecology & Evolution,* Vol. 30, Issue 9, 2016, pp 902 ff; J. ROCKSTROM et al., A *safe Operating Space for humanity,* in *Nature,* vol. 461, 2009, pp. 472 ff; ID. *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*, in *Ecology and Society*, vol. 14, Issue 2, 2009, pp. 32 ff. In this context, see also POPE FRANCIS, *Encyclical Letter Laudato Si' on Care for Our Common Home*, 24 May 2015, Vatican Press. The encyclical has played a crucial role in linking scientific insights on planetary boundaries and ecological crises with a broader ethical and legal discourse. By framing sustainability as both a moral duty and a legal imperative, the concept of planetary limits has been disseminated within political and juridical debates, influencing global frameworks such as the UN 2030 Agenda and the European Green Deal.

[31] On this point, see F. FRACCHIA, *I doveri intergenerazionali. La prospettiva dell'amministrativista e l'esigenza di una teoria generale dei doveri intergenerazionali,* in P. PANTALONE (ed.), *Doveri intergenerazionali e tutela dell'ambiente. Sviluppi, sfide e prospettive per Stati, imprese e individui,* Stem Mucchi Editore, Modena, 2021, pp. 55 ff. See, also F. CIARAMELLI, F.G. MENGA (eds..), *Responsabilità verso le generazioni future. Una sfida all'etica, al diritto e alla politica,* Editoriale Scientifica, Napoli, 2017. See also, A. D'ALOIA, *La Costituzione e il dovere di pensare al futuro,* in *BioLaw Journal - Rivista di BioDiritto,* 2, 2022, pp. 1 ff., https://doi.org/10.15168/2284-4503-2356.

[32] UN, General Assembly, Res. A/RES/70/1 of 25 September 2015, *Transforming our world: the 2030 Agenda for Sustainable Development*.

no one behind»[33] into tangible results, at the European level, the challenge has been embraced by the Green Deal (hereinafter GDE*)*[34] and its implementing tools[35].

[33] *Funditus,* A. LA CHIMIA, *Procurement and sustainable development in the 2030 Agenda,* in L. FIORENTINO, A. LA CHIMIA (eds..), *Il* Procurement *delle Pubbliche Amministrazioni,* Il Mulino, Bologna, 2021, 73 ff. In general, for a comprehensive overview of the concrete implications of public power in terms of sustainability, see F. DE LEONARDIS, *Lo stato ecologico, cit,* pp. 245 ff.

[34] Adopted by Communication from the European Commission, *The European Green Deal, Brussels,* 11.12.2019 COM (2019) 640 final. Specifically, the document emphasises that the EGD aims to implement «ambitious measures to tackle climate change and environmental challenges, to limit global warming to 1.5ºC and avoid massive biodiversity loss». The act illustrates and frames the initiatives that the Commission will present as part of the Work Programme for implementing a just and inclusive transition to a sustainable economy in the European Union. The capillarity and multi-level perspective of the GDE emerges from the aforementioned Commission Communication, which states: «A new pact is needed that brings together citizens, in all their diversity, national, regional and local authorities, civil society and industry, in close cooperation with the Union's institutions and advisory bodies». For literature on the GDE, see D. BEVILACQUA, *Il Green New Deal,* Giuffré, Milano, 2024; D. BEVILACQUA, E. CHITI, *Green Deal. Come costruire una nuova europa,* Il Mulino, Bologna, 2024; N. CHOMSKY, R. POLLIN, *The Climate Crisis and the Global Green New Deal: The Political Economy of Saving the Planet,* Verso Books, 2020; ID., *Minuti contati. Crisi climatica e Green New Deal globale,* Ponte delle Grazie, Milano, 2020; A. PETTIFOR, *The Case for the Green New Deal,* Verso Books, 2019; ID., *Il Green New Deal. Cos'è e come possiamo finanziarlo,* Fazi Editore, Roma, 2020.

[35] By implementing corollaries of the European Green Deal, one may refer, inter alia, to: the «European Climate Law», Regulation 2021/1119/EU, establishing the framework for achieving climate neutrality; the «Fit for 55 legislative package» (COM(2021) 550 final, 14 July 2021); the «Just Transition Mechanism» (COM(2020) 22 final, 14 January 2020, and Regulation 2021/1056/EU establishing the Just Transition Fund); the «EU Biodiversity Strategy for 2030» (COM(2020) 380 final, 20 May 2020); the «Farm to Fork Strategy» (COM(2020) 381 final, 20 May 2020); the «Circular Economy Action Plan» (COM(2020) 98 final, 11 March 2020); «EU Taxonomy Regulation» 2020/852/EU, establishing a framework to facilitate sustainable investment; the «Strategy for Financing the Transition to a Sustainable Economy» (COM(2021) 390 final, 6 July 2021); and the «Zero Pollution Action Plan» (COM(2021) 400 final, 12 May 2021).

In its 116 points, this document sets out a cross-cutting and mission-oriented political project aimed at synthesising public interventions and private initiatives to contribute to the realisation of a sustainable economy, within the process of European integration.

The shift of the economy towards green solutions is one of the main pillars of the concept of ecological transition. However, this creates a need for an integrated redesign of existing economic systems and raises questions about the role that public authorities, industries, and consumers should play in this new framework.

Making the economy work for the environment involves reinterpreting concepts like competition and private economic initiative, which requires the market to accept variables outside its usual dynamics of supply and demand. The primary goal, therefore, is to enhance the environment[36], through the spread of *the blue economy*[37], a model where economic activity does not just avoid damages, but also aims for environmental and social regeneration goals.

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[36] However, this theory has faced criticism: Serge Latouche challenges the very idea of producing more with his theory of degrowth, arguing that true sustainability comes from reducing consumption and rediscovering sobriety. See, S. LATOUCHE, *La décroissance,* Humensis, Paris, 2024. On page 7, the author states: «Le projet de la décroissance n'est ni celui d'une autre croissance, ni celui d'un autre développement (soutenable, social, solidaire, etc.), mais bien la construction d'une autre societé, une societé d'abundace frugale, une societé d'abondance frugale, une societé "postcroissance" [..]». Among scholars, see also, M. PALLANTE, *La Décroissance heureuse. La qualité de la vie ne dépend pas du PIB,* Nature et Progrès, Namur, 2011 and *P*. RABHI, *Vers la sobriété heureuse,* Arles, Actes Sud, 2010.

[37] See G. PAULI, *The Blue Economy: 10 years. 100 innovations. 100 million jobs,* Paradigm Pubns, Boulder, 2010; ID. *The Blue Economy 3.0: The Marriage of Science, Innovation and Entrepreneurship Creates a New Business Model That Transforms Society* ,Xlibris, Bloomington, 2017*; R*. FERRARA, *Brown economy, green economy, blue economy: l'economia circolare e il diritto dell'ambiente,* in F. DE LEONARDIS (ed.), *Studi in tema di economia circolare*, Eum Editore, Macerata, 2019, pp. 48 ff.

This new era of public authorities taking the lead on environmental issues[38], which the European Union broadly promotes[39], is also evident in the constitutions of individual Member States. These constitutions, in most cases, merely recognise ecological protection as a systemic constitutional principle. From a comparative perspective, however, it can be said that very few constitutions explicitly legitimise the need for a green economy. In this context, reference is made to the constitutional reforms[40] that have taken place in France[41], Croatia[42], and Italy[43].

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[38] Among scholars, see B. CELATI, *Stato e mercato nella disciplina giuridica del "governo dell'economia sostenibile",* in *Amministrazionecammino,* 2021,5; ID. *L'intervento pubblico per la riconversione ecologica dell'economia,* CEDAM, Padova, 2021.

[39] For a general overview on this topic, reference is made to E. CHITI, *Introduction to the Symposium: Managing the Ecological Transition of the European Union,* in *RQDA,* 1, 2021, pp. 99 ff.

[40] For an in-depth analysis on the subject, see C. PIZI, *Rapporto tra economia e ambiente nel costituzionalismo ambientale europeo: un confronto tra Italia, Francia e Belgio,* in *DPCE Online*, 58, 2023, pp. 423 ff. https://doi.org/10.57660/dpceonline.2023.1895 .

[41] Article 6 of the French Environmental Charter, constitutionalised by Constitutional Law 205/2005, states that «Les politiques publiques doivent promouvoir un développement durable. A cet effet, elles concilient la protection et la mise en valeur de l'environnement, le développement économique et le progrès social». On this point, see M. ZINZI, *La Charte de l'environnement francese tra principi e valori costituzionali. Profili di diritto comparato*, Editoriale Scientifica, Napoli, 2011.

[42] Article 50 of the Croatian Constitution states: «Free enterprise and property rights may be exceptionally limited by law to protect the interests and security of the Republic of Croatia, nature, the environment, and health» (free translation)

[43] Addressing Articles 9 and 41 of the Constitution, Constitutional Law 1/2022 has incorporated into constitutional language the principles of environmental protection, diversity, and ecosystems in the interest of future generations, and has defined the environment, health, and environmental objectives as the finalistic elements of economic activity. *Funditus*, P. LOMBARDI, *Ambiente e generazioni future: la dimensione temporale della solidarietà*, in *Federalismi*, 1, 2023, pp. 86 ff. A. D'ALOIA, *La Costituzione e il dovere di pensare al futuro*, cit, pp.1 ff.; I. RIVERA, *Le tonalità dell'ambiente e le generazioni future nel cammino di riforma della Costituzione*, in *BioLaw Journal*, 2022, 2, pp.225 ff.; M. CECCHETTI, *La riforma degli articoli 9 e 41 Cost.: un'occasione*

In any case, giving the environment a leading role in political strategies and constitutional texts has the benefit of making sustainability a key guiding parameter. However, to ensure these provisions do not remain merely on paper, they must be supported by tools capable of making them effective[44].

In this view, Next Generation EU[45] (hereinafter NGEU) and the associated National Recovery and Resilience Plans[46] have become key drivers: while the

mancata per il futuro delle politiche ambientali?, in *Forum di Quaderni costituzionali*, 2022, 2, pp. 352 ff.; Y. GUERRA, R. MAZZA, *La proposta di modifica degli articoli 9 e 41 Cost.: una prima lettura*, in *Forum di Quaderni costituzionali*, 2021, 4, pp. 109 ff.; G. SANTINI, *Costituzione e ambiente: la riforma degli artt. 9 e 41 Cost., ivi*, 2021, 2, pp. 460 ff.

[44] On this point, reference is made to M. WASMEIER, *The integration of environmental protection as a general rule for interpreting Community law,* in *Common Market Law Review,* 1, 2001, pp. 159 ff and M. WENNERÅS, *Towards an ever-greener Union? Competence in the field of the environment and beyond,* in *Common Market Law Review,* 6, 2008, pp. 1645 ff.

[45] Next Generation EU is the recovery and resilience facility for EU Member States following the pandemic crisis. The latter, amounting to a total of €723.8 billion, offers grants and loans to support reforms and investments in Member States. These states are required to draw up national recovery and resilience plans, setting out how they intend to invest the funds and meet the agreed targets and objectives. In fact, before any disbursement under the Recovery and Resilience Facility, the Commission assesses whether each milestone and target has been satisfactorily achieved. For more details, see Communication COM (2020) 456 final, 27 May 2020, *Europe's moment: repairing the damage and preparing for the future for the next generation.* In July 2020, EU heads of state or government approved *Next Generation EU.* On 10 November 2020, the agreement was also signed with the European Parliament. On 17 December 2020, the Council of the European Union adopted the relevant 2021-2027

[46] About the impact of Next Generation EU on individual national Recovery and Resilience Plans, the Italian model has undoubtedly attracted the most interest, given the substantial sum of over €190 billion granted by the European Union (established by Regulation 2021/241/EU).The Italian NRRP was approved by the ECOFIN Council on 13 July 2021 and subsequently amended by the Council Implementing Decision of 8 December 2023. At the national level, the legal framework includes: Decree-Law No. 59 of 6 May 2021 (converted, with amendments, by Law No. 101 of 1 July 2021), establishing the Complementary Fund to the NRRP; Decree-Law No. 152 of 6 November 2021 (the so-called PNRR Decree), containing urgent measures for the implementation

reformed constitutional texts and European political strategies establish new axiological horizons for public action, financial and planning instruments such as NGEU provide the resources to turn those objectives into concrete investments and structural reforms.

In this context, however, it should be remembered that the role of the state as an incentiviser and planner cannot be considered eternal[47]. The natural limitations of public resources compel us to reflect on a specific aspect: the state must intervene during systemic crises, such as the ones we are currently experiencing, to establish new principles and make necessary public resources available. Nonetheless, any solution becomes futile and temporary if the strategic role of private actors is not considered in this context[48].

The private actor *par excellence* is the business sector, which, as is well known, pursues profit as its primary objective. The task of public authorities, therefore, is to promote a shift in the production system, creating the necessary

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of the Plan; Decree-Law No. 36 of 30 April 2022 (PNRR 2 Decree), aimed at ensuring the achievement of milestones due by 30 June 2022; and Decree-Law No. 19 of 2 March 2024, converted with amendments by Law No. 56 of 29 April 2024, introducing further urgent measures in connection with the revised NRRP. The final text of the PNRR divides the mission inherent in the Green Revolution and ecological transition into four components: 1. Sustainable agriculture and circular economy 2. Renewable energy, hydrogen, network, and sustainable mobility 3. Energy efficiency and building renovation 4. Protection of the territory and water resources. In addition to the approximately € 60 billion allocated by the PNRR, approximately € 9 billion from the National Complementary Fund has been allocated to the Ecological Transition mission. For a general overview of the scope of the PNRR, see M. MIDIRI, *Il tempo delle funzioni pubbliche (a proposito del Piano nazionale di ripresa e resilienza),* in *Federalismi,* 18, 2022, pp. 148 ff. and N. LUPO, I *poteri dello Stato italiano alla luce del PNRR: prime , ivi.*, 23, 2022, *paper.* See also, F. GALASSO, *Il Pnrr propulsore della innovazione manageriale della pubblica amministrazione,* in *Rivista Italiana di Public Management*, *5*(1),2022, pp. 2533 ff.

[47] See, F. DE LEONARDIS, *Lo Stato ecologico,* cit. p.164.

[48] For some reflections about so-called industrial ecology, see J.B. FRESSOZ, *La main invisible a-t-elle le pouce vert?,* in *Techniques & Culture,* 65-66, 2016, pp. 324 ff.

conditions for the industrial sector to view environmental protection not only as an ethical duty but also as an opportunity for profit.

The main goal is to guide industry towards the so-called "strong sustainability"[49], a paradigm according to which the economic system (as a subsystem of the natural system) must adapt to the ecological limits of the planet, in full accordance with the precautionary principle[50].

By emphasising the importance of ecological limits over economic development, the implementation of a strong sustainability paradigm could promote a wider recognition of the principle of non-regression (developed in doctrine[51] and

[49] This theory contrasts with the paradigm of «weak sustainability», according to which natural and human capital are merely substitutable. For further information on this topic, see N. GEORGESCU-ROEGEN, *The Entropy Law and the Economic Process*, Cambridge, Harvard University Press, 1971; M. CAFAGNO, *Analisi economica del diritto e ambiente, tra metanarrazioni e pragmatismo,* in *Il diritto dell'economia, 2*, 2019, pp. 155 ff.

[50] This principle was initially set out in Article 15 of the Rio Declaration and is expressly recognised in Article 191 of the TFEU. As the relevant doctrine is very broad, here is a brief overview on the topic: MANFREDI, *Note sull'attuazione del principio di precauzione in diritto pubblico*, in *Diritto pubblico*, 3, 2004, pp. 1075 ff.; F. TRIMARCHI, *Principio di precauzione e "qualità" dell'azione amministrativa*, in *Rivista Italiana di Diritto Pubblico Comparato*, 6, 2005, pp. 1673 ff; F. DE LEONARDIS, *Il principio di precauzione nell'amministrazione di rischio*, Giuffrè, Milano, 2005, pp. 288 ff; L. BUTTI, *Principio di precauzione, Codice dell'ambiente e giurisprudenza delle Corti comunitarie e della Corte costituzionale*, in *Rivista giuridica dell'ambiente*, 6, 2006, pp. 809 ff; A. ZEI, *Principio di precauzione*, in *Digesto delle discipline pubblicistiche*, Utet, Torino, III, pp. 670 ff.; M. ALLENA, *Il principio di precauzione: tutela anticipata v. legalità-prevedibilità dell'azione amministrativa,* in *Il Diritto dell'Economia*, 2, 2016, pp. 411 ff.

[51] M. PRIEUR, G. SOZZO (eds.), *La non régression en droit de l'environnement,* Brussels, Bruylant, 2012; M. PRIEUR, *Non-regression in environmental law,* in S.A.P.I.EN.S., 2, 2012, pp. 53 ff.; ID., *Une vraie fausse création juridique: le principe de non-régression,* in *RQDA, 2*, 2016, pp. 136 ff.; J. MAKOWIAK, *The principle of non-regression: an unknown quantity in the house*, in *RQDA*, 3, 2019, pp. 12 ff. The issue has appeared in the Italian literature, seemingly as a reflex. See, M. MONTEDURO, *Crucialità, criticità e complessità del dibattito sul principio di non regressione ambientale*, in *RQDA,* 1, 2021*,* pp. 4 ff; *S*. CANDELA, *Il principio di non regressione ambientale*

increasingly acknowledged internationally[52]), according to which it is not permissible to reduce the level of environmental protection already achieved in favor of temporary economic interests. From this perspective, therefore, the legal system must focus on consolidating (rather than dismantling) the regulatory and institutional progress already achieved in the environmental field.

Because industrial policies need to better align with environmental protection objectives, it is essential to focus on the production model best suited to these purposes. In this sense, it is fundamental to examine the role of the circular economy[53] within the context of European industrial strategy.

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all'interno dell'ordinamento giuridico italiano: indici di emersione e prime iniziative di riconoscimento, in *RQDA,* 1, 2021, pp. 30 ff. N. GRANATO*, Il principio di non-regressione come nuova frontiera del diritto dell'ambiente: profili e problemi*, in *GiustAmm*.it, n. 3/2020.

[52] Consider the 2015 Paris Agreement, which, in the preamble, highlights «the need for an effective and progressive response to the urgent threat of climate change that builds on the best available scientific knowledge [...]». In Art. 3, it emphasizes that «the efforts of the Parties will track, over time, a progression [...]». In Art. 4(3), it states that «each nationally determined contribution of a Party represents a progression from the previous nationally determined contribution, and reflects the highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances». Additionally, Art. 4(11) provides that «a Party may, at any time, adjust its current nationally determined contribution in order to improve its level of ambition [...]». The World Declaration on the Environmental Rule of Law, approved in 2016 in Rio de Janeiro following the well-known World Environmental Law Congress, proposed the codification of the principle of non-regression, along with the recognition of a principle of progression. Among the initiatives, always at the international level, it is worth mentioning the establishment of the «Global Legal Observatory on Non-Regression», the «Draft International Pact» relating to the right of man to the environment (proposed by the Centre International de Droit Comparé de l'Environnement), and the «Global Pact for the Environment» project, the result of an initiative promoted in France by the Club des Juristes.

[53] See M. MAILLEFERT, *Du développement durable à l'économie circulaire: comment passer d'une politique d'accommodement à une transition vers un changement de modèle?* in *Revue Juridique de l'Environnement, 3*, 2024, pp. 525 ff.

1.4 Understanding the Circular Economy: From Concept to Legal Principle

Indeed, one of the main *pillars* underlying the GDE is the vision of an economy where production and consumption methods align with ecological limits. The reference is to the circular economy paradigm[54], a model of production and consumption – as opposed to the traditional linear model[55] – centered on biomimicry[56].

Given its regenerative potential and ability to create closed systems where the same resource can be reused across multiple production and consumption cycles[57] , the development paradigm of the circular economy cannot be simplistically dismissed as a mere idea of a conservative approach to the environment.

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[54] The most authoritative definition of the circular economy is that developed by the Ellen MacArthur Foundation. This organisation promotes the circular development paradigm worldwide: «*circular economy* is a conceptually regenerative industrial economy that mimics nature by actively improving and optimising the systems through which it operates». As is well known, the concept of the circular economy has been of interest to economists for many years. The starting point was the 1983 *Brundtland* Report, which highlighted the unsustainability of the so-called linear system even then. However, the legal effort to regulate the circular economy is particularly relevant today and, as we shall see, dates back less than a decade. *Funditus,* M. COCCONI, *LA regolazione dell'economia circolare,* Franco Angeli, Milano, 2020, pp. 16 ff.; F. DE LEONARDIS, *Economia circolare: saggio sui suoi diversi aspetti giuridici,* in *Diritto Amministrativo,* 1, 2017, pp. 163 ff.

[55] This is the traditional model of economic development, which is based on the sequence take–make–dispose. In this open system, natural resources are extracted from the environment, transformed, consumed, and discarded without being recovered.

[56] On this point, reference is made to J. BENYUS, *Biomimicry: Innovation Isnpired by Nature*, HarperCollins, New York, 2020.

[57] F. DE LEONARDIS, entry on *Circular Economy (public law),,* in *Digesto delle Discipline Pubblicistiche*, Utet Giuridica, Torino, 2021, pp. 165 ff.

It is interesting to note that the circular economy can be seen both as an objective and as a tool of the GDE, along with various measures related to its implementation[58]. Regarding the circular economy as an objective of the GDE, one only needs to look at the «Action Plan for the Circular Economy»[59], a document aimed at defining a strategic framework for the production and consumption of sustainable products within an efficient market, including for secondary raw materials, as well as the various national strategies on the circular economy that have followed one another over the years. By way of example, we refer briefly to the Italian «National Strategy for the Circular Economy»[60] of 2022, as well as the French «Feuille de route pour l'économie circulaire»[61] (FREC) of 2025: significant public planning documents setting out objectives, measures, and actions aimed at a circular ecological transition planned for the medium to long term. Among its many goals, this strategy seeks to promote new production and consumption habits aimed at steering market dynamics towards more eco-sustainable horizons[62].

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[58] On this point, see D. BEVILACQUA, *L'economia circolare, il Green Deal e i poteri pubblici,* in M. COCCONI (ed.), *Il mosaico dell'Economia circolare. Regole, Principi, Modelli,* Franco Angeli, Milano, 2023, pp. 45 ff. On p. 53, the author emphasises that the GDE uses the circular economy as one of many public measures to achieve this goal, i.e., as a tool to reduce pollution and waste and, at the same time, to create growth and widespread well-being.

[59] See European Commission, *A new Circular Economy Action Plan For a cleaner and more competitive Europe* COM(2020) 98 final.

[60] See Ministry for the Ecological Transition, *National Strategy for the Circular Economy,* June 2022, available on the website of the Italian Ministry of the Environment and Energy Security (MASE): https://www.mase.gov.it/pagina/strategia-nazionale-leconomia-circolare .

[61] Ministry for Ecological Transition and Territorial Cohesion, *Feuille de route pour l'économie circulaire (FREC)*, 2025, available on the official website of the French Ministry: https://www.ecologie.gouv.fr/feuille-route-economie-circulaire-frec

[62] Significant examples in Italy include measures to reduce packaging waste and strengthen extended producer responsibility (EPR), as well as tax and financial incentives to encourage the reuse of materials and the eco-design of products, and to increase the use of secondary raw materials in industrial processes. Regarding the French strategy, the 2025 FREC builds on the provisions of

However, as doctrine[63] points out, the circular economy also shapes fundamental changes in economic-productive models. For example, consider how European and national institutions have employed typical parameters of the circular economy by modifying current regulations, thereby impacting production and consumption patterns. In 2015, the European Commission presented the European Parliament with the proposal for the so-called «Circular Economy package», which included the Communication «Closing the loop: an EU action plan for the circular economy»[64] and various legislative proposals for the revision of specific directives[65] as integral parts. Then, in 2017, the European Parliament approved the «Second Circular Economy Package» by a large majority, focusing on a marked shift in waste management[66] .

A notable example at the national level of how the circular economy can shape the legal system and bind economic actors is provided by France. French Law 105/2020, known as the «Loi anti-gaspillage pour une économie circulaire» (AGEC)[67], has had a drastic impact on production and consumption patterns (serving as a trailblazer for the European Union on specific issues)[68]. Additionally,

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the 2020 AGEC law, including the gradual ban on certain single-use products, the reintroduction of a deposit system for glass, and the promotion of repair and reuse platforms.

[63] D. BEVILACQUA, *L'economia circolare, il Green Deal e i poteri pubblici, cit,* pp. 63 ff.

[64] See Communication COM (2015) 614 final, 2 December 2015.

[65] This refers to the Waste Framework Directive 2008/98/EC, the Packaging Directive 1994/62/EC, the Waste Electrical and Electronic Equipment Directive 2000/53/EC, and the Landfill Directive 1999/31/EC.

[66] The Circular Economy Package consists of four directives on waste: Directive 2018/851/EU on waste; Directive 2018/852/EU on packaging; Directive 2018/850/EU on landfills; Directive 849/2018/EU on end-of-life vehicles, batteries and WEEE.

[67] C. ANDRIEU, A. DEBOUTIERE, E. DURANT et al., *Économie circulaire: passez à l'action, la loi du 10 février 2020 décryptée et illustrée,* Éditions Législatives, Saint-Amand-Montrond, 2020.

[68] Among the more than one hundred articles of the law under consideration, the introduction of a ban on certain single-use packaging, the extension of extended producer

considerthe establishment of the «Conseil national de l'économie circulaire» (CNEC), an advisory body aimed at monitoring and guiding the implementation of public policies in this area.

Borrowing specific categories from Aristotelian philosophy, the «tool-objective» pairing – which is an integral part of the circular economy – can be linked to the concepts of «being potential» and «being actual». The circular economy is considered «in potential» when public authorities define it as a goal to be pursued through strategies and policy guidelines; it is «in actual» when its principles influence the current regulations of various legal systems.

To date, the concept of circularity is undergoing a significant evolution which, according to some scholars[69], has laid the foundations for a new principle of circularity. This principle is seen as an organising criterion, an accurate compass capable of guiding regulatory production, jurisprudential interpretation, and public policy. Alongside principles such as precaution, prevention, polluter pay, and non-regression, it would become the systemic foundation of a strong sustainability law.

Although this last aspect still relates to a *de iure condendo* perspective, it emphasizes that circularity has the capacity to address a genuine eco-transformative emergency[70] characterized by limited raw materials, energy supply challenges by EU Member States, and unsustainable production and consumption models.

Finally, within this overall framework, the European strategic plan continues to take shape through the Circular Economy Act, which coordinates and

responsibility schemes, and the introduction of measures against planned obsolescence and in favour of reuse and repair stand out.

[69] See S. VERNILE, *Dall'economia circolare al principio di circolarità,* Giappichelli, Torino, 2024.

[70] *Funditus,* see B. BOSCHETTI, *Eco-design giuridico (trasformativo) per la "net-zero age",* in *Istituzioni del Federalismo,* 4, 2022, pp. 821 ff.

consolidates the existing EU regulatory framework on the circular economy[71]. The aim is to develop an integrated and binding framework within a systemic vision of circularity, enhancing European industrial resilience and the competitiveness of the single market. The adoption of this measure, currently preceded by a phase of public and institutional consultation, also presents an opportunity to involve businesses, citizens, and national administrations in a multi-level dialogue aimed at identifying concrete application tools, tailored to different production and territorial contexts[72].

For the sake of completeness, it should be noted that some scholars[73] have highlighted certain conceptual and operational critical issues with regard to the circular economy paradigm: it has been pointed out that this aspect may be linked to broad and sometimes indeterminate theoretical boundaries, often linked to technocratic development agendas that do not take concrete data into account.

[71] While recognising the potential of the future Circular Economy Act in terms of coordinating and rationalising the European regulatory framework for circularity, its possible structural limitations cannot be ignored, such as the fact that a predominantly technocratic approach may not adequately address deeper issues such as economic growth models, social inequalities, behavioural changes and power asymmetries between economic actors. The Circular Economy Act cannot afford to aim merely at optimising material flows, but must promote structural transformations, strengthen the social dimension of the transition and steer the behaviour of operators and consumers towards ecologically compatible models.

[72] For more on the importance of public participation tools, see S. CASSESE, *La partecipazione dei privati alle decisioni pubbliche,* in *Rivista Trimestrale di Diritto Pubblico,* 1, 2007, pp. 13 ff. See also, G. PEPE, *Il modello della democrazia partecipativa fra teorici e profili applicativi,* CEDAM, Padova, 2020, pp. XII ff.

[73] On this point, see K. STEENMANS, F. LESNIEWSKA, *Limitations of the circular economy concept in law and policy*, in *Frontiers in Sustainability,* 4:1154059, 2023; CORVELLEC, A. F. STOWELL, N. JOHANSSON, *Critiques of the circular economy,* in *Journal of Industrial Ecology*, Yale University, 26(2), pp. 421 ff; F. VALENZUELA, S. BÖHM, *Against wasted politics: A critique of the circular economy,* in *EphemeraJournal,* 17(1), 2017, pp. 23 ff.

There is also criticism of the tendency of many public policies to favour recycling strategies at the expense of more transformative approaches.

1.5 The Concrete Challenges of Circularity: From Industrial Symbiosis to Food Sustainability

1.5.1 An Overview

Having outlined the role of the circular economy in public policy, we will now focus on the main challenges it faces.

The "upstream" challenges are driven by the need to minimise the high risk of supply disruption of raw materials in Europe and the need to promote the continuous implementation of eco-design. Regarding the first point, particular attention is paid to critical raw materials, such as metals, minerals, and natural resources essential for the functioning and integrity of a wide range of industrial ecosystems[74]. As is well known, the geopolitics of critical raw material supply shows that these are mainly sourced outside the European continent, leading to a strong dependence of the EU on other countries[75] .

[74] Critical raw materials include: Aluminium/bauxite/alumina, Coking coal, Lithium, Phosphorus, Antimony, Feldspar, Scandium, Arsenic, Fluorspar, magnesium, metallic silicon, barite, gallium, manganese, strontium, beryllium, germanium, natural graphite, tantalum, bismuth, hafnium, niobium, metallic titanium, boron, helium, tungsten, cobalt, phosphorite, vanadium, copper, and nickel.

[75] In this regard, it should be noted that, for some critical raw materials, the EU depends exclusively on one country: China supplies 100% of the EU's heavy rare earth elements; Turkey supplies 98% of the EU's boron; South Africa supplies 71% of the EU's platinum. For a broad overview of this issue, with particular emphasis on WEEE, see A. PELLEGRINI, *Una nuova visione circolare per i rifiuti elettronici,* in *Federalismi,* 11, 2014, pp. 122 ff.

Regulation 2024/1252/EU[76] aims to strengthen the EU's self-sufficiency in this area. Additionally, the European Union has deemed it necessary to adopt measures to enhance the circularity and sustainability of the raw materials most consumed within the Union. This includes strengthening recycling efforts[77] and supporting research and innovation in resource efficiency and substitute development.

In addition to the package of directives aimed at changing the pace in waste management, the European Commission's push for the circular economy has led to the *ESPR* regulation*,* Ecodesign for Sustainable Products Regulation»[78], which came into force last July[79]. It aims to expand the scope of the Ecodesign Directive

[76] Specifically, Regulation 2024/1252/EU establishes a framework to ensure a secure and sustainable supply of critical raw materials and amends Regulations 2013/168/EU, 2018/858/EU, 2018/1724/EU, and 2019/1020/EU.

[77] See, for example, recital 51 of this Regulation: «Most critical raw materials are metals, which can generally be recycled indefinitely, although sometimes with a decline in quality. This presents an opportunity to foster a truly circular economy within the green transition by increasing the availability of critical raw materials and enhancing supply security. After an initial period of rapid demand growth for critical raw materials for new technologies—when primary extraction and processing remain the main sources—recycling should progressively diminish the reliance on primary extraction and its impacts. Achieving this requires maintaining high recycling capacity in the Union through a robust market for secondary critical raw materials. However, current recycling rates for most critical raw materials are low, as shown by waste streams like batteries, electrical and electronic equipment, and vehicles being exported for recycling. Recycling systems and technologies often do not suit the specific needs. of these raw materials. Innovation is crucial for reducing dependency on critical raw materials, mitigating supply risks, and developing recycling technologies that safely and securely recover critical raw materials from waste. Prompt action is necessary to overcome the various obstacles preventing the realization of this potential circularity».

[78] See the Communication from the European Commission, *Sustainable Products: From Exception to Rule,* COM (2022) 40 final.

[79] The specific reference is to Regulation 2024/1781/EU, which establishes the framework for setting eco-design requirements for sustainable products, amends Directive 2020/1828/EU and Regulation 2023/1542/EU, and repeals Directive 2009/125/EC.

to cover a broader range of products than initially planned. The idea is to turn what was previously an exception into a rule, while also preventing risky distortions of the European market caused by differing regulations.

From a "downstream" perspective, extending products' life cycle as much as possible is the goal of the «Right-to-Repair» (or R2R) directive[80]*:* a measure that supplements EU initiatives on eco-design and consumer empowerment in the era of green transition, which Member States must transpose within 24 months of its entry into force. In summary, this directive obliges manufacturers of consumer products to ensure timely and affordable repair services and to inform consumers about their right to repair. The aim is to strengthen and reduce the costs of the repair market, guiding consumers towards reconditioned choices.

Given that one of the primary targets of EU public policy is to adopt more sustainable production systems and practices, it should be noted that the target instrument of circularity is a significant common denominator in public policy actions within market dynamics (an aspect represented by the broad category of market instruments for environmental protection)[81], as well as the various

[80] The reference is to Directive 2024/1799/EU, which establishes standard rules promoting the repair of goods and amends Regulation 2017/2394/EU and Directives 2019/771/EU and 2020/1828/EU. As highlighted in point 3) of the previous Commission Communication COM, 2023, 155 final, this directive is necessary to reduce the premature disposal of functional goods purchased by consumers and to encourage longer use of these goods. It is essential to establish rules on repairing such goods. Repair should support more sustainable consumption, as it is likely to reduce waste from discarded goods and lower the demand for resources, including energy, used in the manufacture and sale of new products.

[81] The topic, touched upon in a cross-cutting manner in this discussion, certainly deserves further study, starting with the earliest contributions on the subject. Among the earliest studies on this point, see M. CLARICH, *La tutela dell'ambiente attraverso il mercato,* in *Diritto Pubblico,* 2007, 219 ff., M. CAFAGNO, F. FONDERICO, *Riflessione economica e modelli di azione amministrativa a tutela dell'ambiente,* in P. DELL'ANNO, E. PICOZZA (eds..), *Trattato di diritto dell'ambiente (Treatise on environmental law),* Vol. I., Principi generali, CEDAM, Padova, 2012, 487 ff.

institutional measures aimed at making European industries a lever for ecological transition in the context of the Green Revolution[82].

One example is the Corporate Sustainability Due Diligence Directive (CSDDD or CS3D)[83], which came into force last July and will be gradually transposed by Member States over the coming years. In line with Article 191 of the TFEU, the directive in question establishes rules aimed at holding large companies responsible for all activities that may have a negative environmental or social impact, both directly and in the context of the company's entire supply chain (for example, the activities of business partners, customers, and suppliers)[84].

Furthermore, consider the importance of so-called non-financial reporting (ESG communication) required of specific companies. The *Corporate*

[82] On this point, see *funditus,* M. COCCONI, *La nuova politica industriale europea verso un modello di crescita circolare rigenerativo,* in ID. (ed), The *Il mosaico dell'economia circolare, cit.,* pp. 25 ff.

[83] Regarding the proposed Directive 2024 on corporate sustainability due diligence, see Communication COM (2022) 71 final, incorporated into Directive 2024/1760/EU. The new legislation amends Directive 2019/1937/EU and Regulation 2023/2859/EU.

[84] The reference is to Directive 2024/1760/EU on corporate sustainability due diligence (Corporate *Sustainability Due Diligence Directive,* or CSDDD or CS3D for short).The new directive concerns certain obligations with regard to negative impacts on human rights and the environment for companies with more than 1,000 employees and €450 million in turnover, which are required to exercise due diligence through activities focused on: integrating due diligence into their policies and risk management systems; identifying and assessing actual or potential adverse impacts; preventing and mitigating potential adverse impacts; remedying actual adverse impacts; engaging in meaningful dialogue with stakeholders; establishing and maintaining a reporting mechanism and grievance procedure; monitoring the effectiveness of the policy and measures relating to due diligence; public communication on due diligence. The directive also stipulates that, in exercising due diligence, companies should consider not only their own activities but also those related to their value chain. Although these provisions primarily concern larger companies, they will also involve smaller companies – including SMEs – with which they interact. These smaller companies will be required to provide data, information, and assessments regularly, as well as comply with specific policies and measures.

Sustainability Reporting Standard Directive[85] has amended the previous regime, expanding the companies' responsibility regarding a sustainable economy[86]. To date, the focus is on genuine sustainability reporting aimed at preventing greenwashing practices as much as possible, improving dialogue between stakeholders, and raising awareness among companies themselves of the risks and opportunities arising from the *business* model adopted.

1.5.2 The Role of Businesses in the Circular Transition

The «New European Industrial Strategy»[87] clearly demonstrates how the circular economy is an industrial tool that is deeply connected to achieving the objectives of climate neutrality[88], reducing the EU's reliance on raw material

[85] The reference is to Directive 2022/2464/EU.

[86] In the literature, see F. CONTE, *La finanza sostenibile: limiti e profili evolutivi,* in *Federalismi,* 33, 2022, pp. 1 ff.

[87] The reference is to the Communication of the European Commission, *A New European Industrial Strategy,* Brussels, 10 March 2020, COM (2020), 102 final. On 5 May 2021, the update of the EU industrial strategy 12 was issued, aimed at strengthening the industrial system in the wake of the Covid-19 experience to better manage the Union's strategic dependencies on foreign markets. For a description of the evolution of European industrial policies, see G. AMATO, Le *politiche industriali dell'Unione Europea dal passato al futuro,* in Il *Mulino,* 4, 2004, pp. 757 ff.

[88] As is well known, climate neutrality itself is one of the main objectives of the GDE, the implementation of which is entrusted to the European Climate Law - i.e. Regulation 2021/1119/EU, establishing the framework for achieving climate neutrality, amending Regulation 401/2009/EC and Regulation 2018/1999/EU - and to the measures contained in the Fit for 55 package, Communication of the European Commission, *Fit for 55: achieving the EU's 2030 climate target on the road to climate neutrality,* COM (2021) 550 final, 14 July 2021. The package sets new *targets* for renewable energy (40% by 2030 – raised to 45% by the REPowerEU proposal) and energy efficiency (9% reduction in demand by 2030 – raised to 13% by the REPowerEU proposal), and reduction of transport emissions (including only zero-emission new vehicles on the EU market from 2035). In addition, it envisages establishing a social climate fund financed by ecological taxation measures to

supplies from third countries, and boosting the competitiveness of the single market. The strategic role of the circular economy is part of a broader challenge: the production system needs integrated European innovation and governance capable of planning and funding strategic supply chains.

In this regard, European institutions have deemed it appropriate to commission high-level reports to assess the state of European industrial strategy and its areas for improvement[89]. The 2024 Letta Report, «Much more than a market – Speed, Security, Solidarity»[90] focused on pinpointing the main challenges of the

substantiate the just green transition. On this topic, see G. MONTI, *The European Climate Law: Making the social market economy fit for 55?*, in *Common Market Law Review,* vol. 58, 5, 2021, p. 1321 ff. For a comprehensive overview with reference to the GDE and climate neutrality, see F. DONATI, *Il Green Deal e la governance dell'energia e del clima,* in *Rivista Giuridica di regolazione dei mercati,* 1, 2022, pp. 13 ff. For a comprehensive reconstruction, from a public law perspective, of the climate issue at the European level, see A. BONOMO, *Il potere del clima,* Cacucci Editore, Bari, 2023. In the introduction, on p. 4, the author emphasises that «action to combat climate change, understood as a duty that also arises from an intergenerational perspective, is a problem that belongs to the sphere of public law. More than any other sector, climate change requires common public policies – shared rules, universal high standards, organisations with far-reaching enforcement powers – capable of imposing uniform procedures and regulatory systems. Moreover, the scale of the measures needed to combat a phenomenon that is neither unexpected nor temporary, but destined to last, is such that the solution cannot be entrusted to individualistic approaches or emergency solutions, but can be more appropriately governed by the instruments, including innovative ones, of public law, the only ones capable of promoting and investing in forward-looking containment policies and ultimately overcoming, in the name of a higher interest, the numerous potentially conflicting individual interests» (free translation).

[89] See, among others, G. MOCAVINI, *I Rapporti Letta e Draghi sul futuro del mercato unico e sulla competitività europea*, in *Rivista Trimestrale di Diritto Pubblico*, 4, 2024, pp. 1318 ff. and M. COCCONI, *L'Unione Europea ad un bivio sul futuro del mercato unico e della competitività europea,* in *Federalismi*, 4, 2025, pp. 144 ff.

[90] E. LETTA, *Much more than a market. Speed, security, solidarity. Report on the future of the Single Market,* Brussels, April 2024, available at the following link: https://ec.europa.eu/commission/presscorner/detail/en/IP_24_1944.

single market and proposing ways to enhance competitiveness. The core of the report lies in defining the internal market as the political capital of European integration within a context of green and digital transitions. However, ongoing regulatory fragmentation and operational barriers, which particularly impact small and medium-sized enterprises (SMEs), restrict their potential, leading to reduced economies of scale and supply networks. In Letta's view, what should be promoted at the European level is Single Market 2.0, where the ecological transition can also drive inclusive growth for SMEs.

Letta's vision is further enriched by the Draghi Report[91], presented to the European Commission a few months later. While the Letta Report focuses on analysing the European internal market, the Draghi Report considers Europe's limitations and competitive capabilities in a global context. Draghi highlights how competitiveness today depends on active industrial policies and strategic investments. A genuine standard industrial policy, involving shared financial tools - including the use of common European debt - greater coordination of national policies, and massive support for technological innovation and frontier research, would seem to be the only viable way forward to prevent emerging macro-powers from stifling the European economy.

This has inspired to the idea of a renewed European industrial contract capable of reconciling economic, social and environmental interests within a single strategic trajectory in which Europe can become a global hub for clean technologies, as already set out in the Net Zero Industry Act (NZIA) of 2024[92] (intended as the first comprehensive attempt to define European legislation for the

[91] See, A. POGGI, F. FABRIZZI, *The new Whatever it takes. Il Rapporto Draghi: ambizioni e difficoltà sul future dell'Europa,* in *Federalismi*, 22, 2024, pp. IV ff; M. DRAGHI, *The future of European competitiveness – A competitiveness strategy for Europe,* 9 September 2024, European Commission, available at: https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en

[92] See Regulation 2024/1735/EU.

production of net-zero emission technologies within the Union)[93] and emphasised by the Competitiveness Compass[94].

This is the context for the von der Leyen Commission's political project, which aims to launch a Clean Industrial Deal (hereinafter CID)[95], intended as a continuation and integration of the GDE.

Among the objectives stated in the CID is the need to accelerate the implementation of the principle of circularity in production cycles, ensuring that SMEs can also benefit from this circular transition[96].

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[93] For an in-depth analysis on this topic, see K. HUHTA, H. KALIMO, N. SOININEN, S. VESA, *EU's Clean Industrial Deal: A Risk or an Opportunity for Sustainability?,* in *European Energy and Environmental Law Review,* 4, 2025, pp. 95 ff. See also, R. VEUGELERS, S. TAGLIAPIETRA, C. TRASI, *Green Industrial Policy in Europe: Past, Present, and Prospects,* in *Journal of Industry, Competition and Trade,* 4, (2024) https://doi.org/10.1007/s10842-024-00418-5

[94] On this point, see European Commission, A *Competitiveness Compass for the EU,* COM (2025) 30 final. It is a strategic initiative by the European Commission designed to strengthen the EU's competitiveness in an era of global economic and technological rivalry. It outlines a new growth model based on productivity, innovation, and sustainability, structured around three transformative imperatives: closing the innovation gap, aligning decarbonisation with competitiveness, and reducing strategic dependencies. The Compass also proposes horizontal measures to simplify regulation, complete the Single Market, mobilise investment, and promote skills and quality employment.

[95] European Commission, *The Clean Industrial Deal: A joint roadmap for competitiveness and decarbonisation,* Brussels, 26.2.2025 COM (2025) 85 final. On this point see D. BEVILACQUA, *Il Clean industrial Deal e la (pRomassa) programmazione della sostenibilità competitiva,* in *RGA online* 1, 2025. The implementation of the CID is subject to the Delivering on the Clean Industrial Deal I document, which includes measures on tax incentives, regulatory adjustments and a new Clean Industrial Deal State Aid Framework (CISAF). The latter will enable Member States to better invest in clean technologies, striking the right balance with the need to avoid distorting competition. At the economic level, the CID aims to mobilise over €100 billion by bringing together European funds (Innovation Fund, InvestEU, Industrial Decarbonisation Bank) and national resources.

[96] Regarding the role of SMEs in the circular transition, see N. TRITTO, J. G. DIAS, F. BASSI, *SMEs Circular Economy Practices in the European Union Multilevel Implications for Sustainability,*

Ultimately, the CID marks an evolutionary step forward in European industrial policy, aiming to combine competitiveness, strategic autonomy, and environmental sustainability. However, it remains to be seen whether the EU will succeed in turning this plan into truly effective measures capable of balancing the needs of Member States with the creation of a cohesive European industry to leads the green transition.

1.5.3 Industrial Symbiosis and the Circular Economy

In the above context, circularity drives the ecological conversion of production systems, with industrial symbiosis serving as one of its most strategic hubs.

Industrial symbiosis[97] refers to an integrated system of resource sharing between different economic operators acting cooperatively. This involves mechanisms where the output of one company becomes the input in the production process of a third company, creating competitive advantages through the sharing of different types of resources (from waste materials to energy gains and skills).

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in *Social Indicators Research,* 175, 2024, pp. 965 ff. https://doi.org/10.1007/s11205-023-03191-w; C. ALLER ARRANZ, M. F. ARROYABE, J. C. FERNÁNDEZ DE ARROYABE, *Organisational transformation toward circular economy in SMEs. The effect of internal barriers*, in *Journal of Cleaner Production*, 3, 2024, https://doi.org/10.1016/j.jclepro.2024.142307, and G. FÖRSTERLING, R. ORTH, *Transition to a circular economy in Europe through new business models: barriers, drivers, and policy making,* in *Sustainability,* 10, 2023, pp. 8212 ff. https://doi.org/10.3390/su15108212

[97] On this point, reference is made to L. CUTAIA, R. MORABITO, *Ruolo della simbiosi industriale per la green economy. Uno strumento innovativo per la chiusura dei cicli di risorse,* in EAI Special, 1, 2012, pp. 44 ff. For an in-depth analysis, see M.R. CHERTOW, *Industrial Symbiosis: Literature and Taxonomy,* in *Annual Review of Energy and Environment,* 25, 2000, pp. 313 ff.

In other words, it is a valuable tool for closing production cycles[98], and reviewing the dynamics of the so-called industrial metabolism[99].

In this framework, the issue of circular districts[100] - which are production areas or territorial systems where companies and local actors collaborate to maximise the efficient use of resources and enhance the reuse of production waste - is still largely unexplored. An interesting aspect of the existing circular districts (such as the Symbiosis Centre Denmark[101] and the French Écopal project in

[98] Reference is made to G. MARCHIANÒ, *L'economia circolare con particolare attenzione ai rifiuti urbani,* ex *d.l. n. 121 del 3 settembre 2020*, in *AmbienteDiritto.it,* 1, 2022, pp. 1 ff. The strategy of industrial symbiosis has been incorporated into both European and national policy frameworks. Directive 2018/851/EU explicitly identifies industrial symbiosis as a means of promoting the reuse and transfer of resources between companies, requiring Member States to adopt appropriate measures to ensure that substances or objects resulting from production processes can be recognised as by-products.

[99] R.U. AYRES, *Industrial Metabolism,* in J.H. AUSBEL, H.E. SLADOVICH (eds.), *Technology and Environment,* Washington D.C., National Academy Press, 1989, pp. 23 ff. According to the A., Industrial metabolism is the concept that describes the set of physical processes through which raw materials, energy and labour are transformed into products and waste. This discipline aims to analyse material and energy flows in society to understand the sources, causes and effects of emissions and waste. Taking the economy as a subsystem of the biosphere as his starting point, the author proposes a systemic approach that enables us to identify inefficiencies, reduce environmental impact, and guide industry towards more sustainable models that align with the principles of the circular economy and industrial symbiosis.

[100] B. CELATI, *L'intervento pubblico per la riconversione ecologica dell'economia, cit,* pp. 73 ff.

[101] The Symbiosis Centre Denmark is regarded as one of the leading European examples of industrial symbiosis. Originating in Kalundborg in the 1970s, it promotes the exchange of resources, energy, and by-products among local companies, becoming an international benchmark for circular economy practices. More information available at: https://symbiosis.dk

Dunkirk[102]) is that virtuous companies, regardless of a specific public programme, sign specific agreements with companies in the area[103].

These experiences highlight the value of a bottom-up approach, where companies - driven by concrete needs to reduce costs and increase economic efficiency - voluntarily cooperate with a self-organising model within industrial symbiosis schemes that can be adapted to local and sectoral characteristics[104] . In this context, companies become laboratories of innovation, where anticipating technological and organisational solutions can pave the way for the evolution of public policies.

However, the lack of clear regulatory frameworks, especially regarding producer responsibility and the classification of industrial materials and waste, creates problems for replicating these innovative models from one geographical context to another. For this reason, the balance between autonomous business initiative and institutional support is undoubtedly crucial.

The implementation of circular districts could provide an opportunity, at the European level, to launch forms of legislative experimentation[105] (inspired by the French model) that allow testing the strengths and weaknesses of a regulatory measure applied in a limited area[106]. This approach would enable testing innovative

[102] The *Écopal* project in Dunkirk (France) is another relevant case of industrial symbiosis and circular district development. It brings together companies, local authorities, and civil society to foster the mutual use of resources and the valorisation of industrial by-products. The initiative demonstrates how collaborative networks at the territorial level can support both economic efficiency and environmental sustainability. More information available at: https://ecopal.fr

[103] *Ibid.,* p.75

[104] See, A. OLIVETTI, *L'ordine politico delle Comunità,* Edizioni di Comunità, ROMA-IVREA, 2014.

[105] See B. CELATI, *L'intervento pubblico per la riconversione ecologica dell'economia, cit,* pp. 72 ff.

[106] In France, Article 37(1) of the Constitution allows for the adoption of normative provisions on an experimental basis, limited in both scope and duration. This legal mechanism,

solutions in limited territorial contexts and then extending them to other Member States.

Furthermore, the development of circular districts introduces opportunities for territorial initiatives that involve not only industries but also collaborations with public and research organizations. These are known as circular hubs, which are territorial innovation ecosystems designed to integrate industrial, technological, and governance aspects.

The European Commission[107] highlights the value of this operational solution in fostering industrial synergy, as it facilitates the creation of authentic mediating spaces connecting digital innovation, environmental sustainability, and participatory governance.

The hub's goal is to develop a circular district centered on energy and material exchange. Unlike traditional models, it emphasizes institutional frameworks - such as multi-stakeholder governance, territorial partnerships, and environmental metrics - along with social elements like civic participation, and technological aspects. Its cycle includes mapping flows, conducting technological experiments, scaling successful models, and ongoing monitoring.

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already applied in various fields, provides a useful model for the development of experimental legislation in the area of circular economy. For an in-depth study of the institution, see F. CROUZATIER-DURAND, *Réflexions sur le concept d'expérimentation legislative (à propos de la loi constitutionnelle du 28 mars 2003 relative à l'organisation décentralisée de la Reépublique),* in *Revue française de droit constitutionnel, 4*, 2003, pp. 675 ff. See also, J. HEBRARD, *De l'expérimentation à la différenciation territoriale: l'expérience française,* in *Italian Papers on Federalism,* 1, 2022, pp. 40 ff.

[107] PUBLICATIONS OFFICE OF THE EUROPEAN UNION, *Hubs for circularity – Keeping local with a global impact*, 2022, https://data.europa.eu/doi/10.2777/938962 . The hubs for circularity (Hubs for Circularity – H4C) are supported within the framework of the Horizon Europe programmes and the European Green Deal, and are situated at the intersection of industrial innovation policies, the circular economy, and territorial cohesion.

The technological component of the hub is realized through the digitization of processes, aligning with the twin transition[108]. Environmental protection is facilitated by sensors, algorithms, and platforms, highlighting key themes such as access, ownership, and data sharing for achieving circularity.

The political framework outlined by the GDE highlights the crucial link between green and digital progress. It should be directly aligned with the European Digital Strategy[109], which sets the context for the Union's key initiatives on data

[108] As defined by the European Commission's Joint Research Centre (JRC), the concept of *"*twin transitions*"* encompasses not merely the simultaneity of two major transformative processes (the green and the digital transitions) but, more importantly, their integration and potential *synergies*. The notion implies that digitalisation and sustainability should advance in a mutually reinforcing manner to foster systemic change within the European economy and society. Nonetheless, the degree to which these transitions effectively converge, rather than evolve as distinct or even competing processes, remains a matter of ongoing debate and empirical investigation. S. MUENCH, E. STOERMER, K. JENSEN, et al., *Towards a Green and Digital Future (No. EUR 31075 EN)*. Luxembourg, Publications Office of the European Union, 2022; Z. KOVACIC, C. GARCÍA CASAÑAS, L. ARGÜELLES, et al., *The twin green and digital transition: High-level policy or science fiction?,* in *Environment and Planning E: Nature and Space*, *7*(6), 2251, 2024 https://doi.org/10.1177/25148486241258046; See also S. KLOPPENBURG, A. GUPTA, SRL. KRUK, et al., *Scrutinizing environmental governance in a digital age: New ways of seeing, participating, and intervening*, in *One Earth* 5, 2022, pp. 232 ff. https://doi.org/10.1016/j.oneear.2022.02.004

[109] See, European Commission, *A European strategy for data*, COM (2020) 66 final This aims to create a single data market that promotes the development of digital technologies to support industrial competitiveness and environmental sustainability, in line with the objectives of the twin transition. From this perspective, digitalisation is considered an enabling tool for the green transition, capable of optimising resource use, improving the traceability of material and energy flows, and enhancing cooperation among public, private, and scientific actors.

and technological innovation, such as the Data Governance Act[110] and the European Data Act[111].

Within the same framework, it is also essential to highlight the increasing role of artificial intelligence (AI)[112], acknowledged as a key technology in managing and improving production processes. In essence, artificial intelligence is

[110] See Regulation 2022/868/EU. It introduces a regulatory framework aimed at strengthening trust in data sharing mechanisms by establishing neutral intermediaries and promoting forms of data altruism, that is, the voluntary sharing of data for purposes of public interest, such as research, innovation, or environmental protection. The regulation encourages the creation of common European data spaces in strategic sectors to facilitate interoperability, transparency, and cooperation between public and private entities.

[111] See Regulation 2023/2854/EU, which establishes harmonised rules on fair access and the use of data, with the aim of ensuring that data generated within the European economy is accessible and reusable in a safe, fair, and competitive manner. The Data Act seeks to overcome barriers to data sharing by promoting interoperable digital infrastructure and encouraging the emergence of new business models based on circularity, energy efficiency, and transparency of production processes.

[112] Regulation 2024/1689/EU, also known as the AI Act. It is the European Union's landmark regulatory framework governing the development, deployment, and use of artificial intelligence systems within the Single Market. Adopted in 2024, it represents the first comprehensive legal framework on AI worldwide. The regulation establishes a risk-based approach, classifying AI systems into different categories — unacceptable risk, high risk, limited risk, and minimal risk — according to their potential impact on fundamental rights, safety, and democratic values. It sets out obligations for providers, deployers, and users of AI systems, focusing on transparency, accountability, and human oversight. The AI Act aims to ensure that AI technologies used in the EU are safe, trustworthy, and aligned with European values, while at the same time fostering innovation and supporting the development of a competitive AI ecosystem. It is closely linked to the broader objectives of the European Digital Strategy and the twin transition, as it promotes the responsible integration of AI into industrial, environmental, and public governance processes. For an in-depth analysis, see C. NOVELLI, F. CASOLARI, A. ROTOLO, et al., *Taking AI risks seriously: a new assessment model for the AI Act,* in *AI and Society,* 39, 2024, pp. 2493 ff. https://doi.org/10.1007/s00146-023-01723-z

a crucial element of the twin transition, playing an active role in creating integrated systems where digital innovation drives ecological progress.

1.5.4 Industrial Symbiosis and the Organic Circular Economy: A Bioeconomic Perspective

One aspect that has not yet been sufficiently explored in the literature[113] and in the debate on the circularity paradigm applied to industry is the necessity to distinguish the circular economy into two distinct subcategories: inorganic and organic.

The inorganic circular economy involves processing technical flows and recycling non-biological materials, like metals, glass, plastic, cement, or electronic components. In this specific dimension, the main objective of circularity is to maintain the value of materials over time through recycling, reuse, repair, regeneration, and eco-design practices. The ultimate goal is to minimise the extraction of new resources by extending the life cycle of products on the market, thereby contributing to more efficient and sustainable materials management.

The organic circular economy, on the other hand, focuses on conserving biological flows. It aims not to disperse the productive potential of materials derived from natural resources, allowing them to be reintroduced into biological cycles without causing adverse environmental impacts. From this perspective, organic matter (such as food and agricultural waste, biomass residues, or compostable bioplastics) can be transformed into new products or resources.

This distinction highlights how the circular economy is a complex system that, through an integrated set of complementary approaches, encompasses different types of production.

[113] On this point, reference is made to F. DE LEONARDIS, *LO Stato ecologico, cit.* pp. 110 ff.

What emerges from the current context, however, is that European and national institutions are paying greater attention to the inorganic dimension of the circular economy rather than the organic one[114]. Therefore, research should focus on exploring the bioeconomy[115] (i.e., the circular economy applied to the organic world) and questioning the legal instruments and areas of intervention necessary for its effective implementation.

The term bioeconomy refers to the potential for exploiting biological resources in the agro-industrial sectors to achieve sustainable economic growth[116]. In this view, reusing organic waste plays a key role as an effective tool for transitioning towards an ecologically oriented revolution.

Intending to promote soil and biodiversity regeneration and recognize that circularity is the winning development paradigm, the bioeconomy offers a concrete boost to ecological and economic transition.

The fact that soil and its riches are non-renewable resources is the starting point; global population growth goes hand in hand with their excessive exploitation,

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[114] Take the 2018 Circular Economy Package as an example. Besides a few references to certain types of organic waste, it mainly deals with the application of the waste hierarchy in the inorganic sector.

[115] On this point, see N. GOERGESCU-ROEGEN, *Bioeconomia. Verso un'altra economia ecologicamente e socialmente sostenibile,* Bollati Boringhieri, Torino, 2003; S.F. PFAU, J.E. HAGENS, B. DANKBAAR, A.J.M. SMITH, *Visions of Sustainability in Bioeconomy Research,* in *Sustainability.* 3, 2014, pp. 1222 ff. https://doi.org/10.3390/su6031222; M.M. BUGGE, T. HANSEN, A. KLITKOU, *What Is the Bioeconomy? A Review of the Literature,* in *Sustainability,* 8 2016, pp. 691 ff. https://doi.org/10.3390/su8070691; A. LEPORE, S. PALERMO, A. POMELLA, *From the green economy to the circular bioeconomy. A new growth paradigm for the South and for the country,* in *Rivista economica del Mezzogiorno,* 2-3, 2021, pp. 523 ff;

[116] Consider, for example, the food, textile, cosmetics, and pharmaceutical. and wood industries. In doctrine, on the potential of the organic circular economy, see F. DE LEONARDIS, *The ecosystem services provided by soil and the importance of its protection: the essential role of organic waste,* in *RQDA,* 1, 2022, pp. 400 ff; ID., entry *Economia Circolare, cit.*, pp. 169 ff.

allowing us to anticipate, on paper, a global scenario characterised by a scarcity of primary resources[117].

In addition to linking all economic activities that use biological resources for the production of materials, food, and energy, bioeconomy also requires the regulation of organic waste flow as effectively as possible within a fully circular approach and the design of environmentally friendly products exploiting biobased outputs[118].

In this context, strategically exploiting organic waste – which accounts for a high percentage of both urban and industrial production waste – can support and

[117] It is no coincidence that the European Commission has recently published new strategic guidelines on this issue, highlighting how the proper use of soil is a necessary precondition for achieving the climate and biodiversity objectives set out in the European Green Deal and the United Nations 2030 Agenda. *See* Communication COM (2021) 699 final, entitled *EU Soil Strategy for 2030 Reaping the benefits of healthy soils for people, food, nature and climate.* on page 2, this document states: «To reap the benefits of healthy soils for people, food, nature and climate, the EU needs. a renewed Soil Strategy that sets out a framework and concrete measures for protecting, restoring and sustainably using soils and that mobilises the necessary societal engagement and financial resources, shared knowledge, sustainable practices and monitoring to reach common objectives». The strategy is closely linked and works in synergy with other EU policies stemming from the European Green Deal. It will underpin our ambition for global action on soil. For more information, see also the proposal for a directive on soil exploitation Communication COM (2002) 179. Soil regeneration and protection are also key objectives of the *Horizon Europe* 2021-2027 research and innovation project. Among scholars, F. DE LEONARDIS, *The ecosystem services provided by soil and the importance of its protection: the essential role of organic waste,* cit, pp. 405 ff. On this point, see also P. PANAGOS, G. STANDARDI, P. BORRELLI, E. LUGATO, L. MONTANARELLA, F. BOSELLO, *Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models,* in *Land Degradation & Development,* 29, 2018, pp. 383 ff.; A. MCBRATNEY, D. J. FIELD, A. KOCH, *The dimensions of soil security,* in *Geoderma,* 213, 2013, pp. 203 ff.

[118] In general terms, with regard to the eco-friendly design of sustainable products, we would like to highlight a recent proposal by the European Commission. We refer to Communication COM (2022) 140 final, entitled *On making sustainable products the norm*.

fuel the much-desired new design and production system. Examples include new textile fibres made from fruit peels, biofuels and biobased fertilisers, and nutraceuticals made from algae[119] .

At the European level, the bioeconomy strategy dates back to 2012[120]; a significant update followed this in 2018[121].

The strategy in question sets five main objectives: to ensure food and nutritional security, to manage resources sustainably, to reduce dependence on non-renewable and unsustainable resources, to mitigate and adapt to climate change, to strengthen European competitiveness, and to increase employment[122].

The pursuit of these objectives depends on the efficiency of three different areas of action[123]. First, the organic sectors need to be strengthened and expanded by unlocking investment and markets[124]; second, local bioeconomic strategies must

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[119] For information on the possibilities for the practical reuse of plant waste, see the interactive platform "Biovoices" https://biovoices.eu/

[120] European Commission, Directorate-General for Research and Innovation, *Innovating for sustainable growth: a bioeconomy for Europe,* Publications Office, 2012.

[121] European Commission, Directorate-General for Research and Innovation, A *sustainable bioeconomy for Europe, strengthening the connection between economy, society and the environment, updated bioeconomy strategy, Publications Office, 2018; Id.*, *Review of the 2012 European Bioeconomy Strategy,* Publications Office, 2018.

[122] In Europe, the bioeconomy is currently worth over €2.3 trillion in annual turnover, employing 8.2% of the EU workforce (18 million jobs), as reported in the 2018 update of the bioeconomy strategy.

[123] European Commission, Directorate-General for Research and Innovation, A *sustainable bioeconomy for Europe strengthening the connection between economy, society and the environment updated bioeconomy strategy, cit.,* pp. 9 ff.

[124] Among the various measures in this regard, it should be noted that the Partnership for a Bio-based Circular Europe (CBE) (2021-2031), established by Regulation 2021/2085/EU, benefits from an EU contribution of EUR 1 billion to strengthen and progressively expand the EU's bio-based sectors at all stages of the innovation cycle. In addition, the European Fund for the Circular Bioeconomy was recently established. This is the first venture capital fund exclusively focused on

be implemented[125] by individual Member States; and third, the actual ecological limits of the bioeconomy need to be understood[126].

The European Commission recently issued a report[127] on the progress of this strategy, documenting its overall very positive development. However, there is a need for action to improve land and biomass demand management and to refine increasingly sustainable consumption patterns. Regarding the achieved objectives, there has been a significant private investment in the bioindustry, a strong spread of the bioeconomy in Central and Eastern Europe - mainly thanks to funding from the European Union - and a growing number of national and regional strategies in this area.

Italy has also recently adopted an *ad hoc* strategy, called «BIT II»[128] . The Italian bioeconomy is a real driving force for innovation and sustainable growth in

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the bioeconomy and circular bioeconomy in Europe and provides funding under Horizon 2020 and from the European Investment Bank.

[125] To this end, the European Commission has set up several working groups with Member States to rapidly establish local bioeconomies in Europe. The European Bioeconomy Policy Forum facilitates the exchange of knowledge and good practices between Member States for the development and implementation of national and regional bioeconomy policies.

[126] To this end, several information systems have been developed, such as the European Forest Information System (FISE), which provides access to forest data and acts as a driver for the development of new harmonised forest information. Another example is the Mapping and Assessment of Ecosystem Services (MAES), which provides information on the condition of terrestrial, marine, and freshwater ecosystems, forming the basis for future policy assessments and developments.

[127] Report COM (2022) 283, *EU Bioeconomy Strategy Progress Report - European Bioeconomy policy: stocktaking and future developments.*

[128] Reference is made to the 2016 document of the Presidency of the Council of Ministers, which promoted the development of an Italian Strategy for the Bioeconomy (BIT), later updated in 2019 (BIT II). The current strategy for the Italian bioeconomy is freely available on the web. The document was drafted by the National Committee for Biosafety, Biotechnology and Life Sciences (CNBBSV), a government support body responsible for developing scientific, production, social

the Mediterranean area[129] . The national «BIT II» strategy aims to interconnect the various sectors of the Italian bioeconomy through an improved governance model – marked by an intense coordination among ministries, regions. and provinces – and more systematic policies, regulations, research funding plans, and infrastructure investments. Furthermore, «BIT II» seeks to increase turnover and employment in the bioeconomy sector by at least 15% by 2030[130] . The main action lines are set out in different intervention perspectives[131] .

France has also proven itself as one of the most active European countries in developing a national strategy for the bioeconomy, aiming to boost the ecological transition and industrial competitiveness significantly. As part of the broader framework of the «Loi sur la Transition Énergétique pour la Croissance Verte»[132], the «Stratégie Nationale pour la Bioéconomie»[133] (adopted in 2017 and updated with a 2018-2020 action plan) is the French government's primary policy tool in this area. It mainly includes strengthening scientific expertise in this field, promoting biosourced products among citizens and businesses, creating synergies

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security, and advisory guidelines at both the national and EU levels on the most current issues concerning biosafety, biotechnology, and life sciences.

[129] In 2021, the production value of the Italian bioeconomy reached almost €365 billion, ranking Italy third in Europe in terms of bioeconomic production value (second only to France and Germany). The data are reported in INTESA SANPAOLO-ASSOBIOTEC, *La bioeconomia in Europa (The Bioeconomy in Europe),* 8th report, December 2022.

[130] On this point, reference is made to the specific Action Plan (2020-2025) for the implementation of the Italian strategy for the bioeconomy, pp. 5 ff.

[131] *Ibid.,* pp. 10 ff.

[132] Loi 2015-992 du 17 août 2015 «relative à la transition énergétique pour la croissance verte». Among scholars, reference is made to AS. DENOLLE, *Commentaire de la loi relative à la Transition Énergétique pour la Croissance Verte, 1*, 2016, pp. 99 ff.

[133] For an authoritative source on France's national bioeconomy strategy and its operational plan, see *A bioeconomy strategy for France: Action plan 2018-2020* available on the website of the French Ministry of Agriculture https://agriculture.gouv.fr/bioeconomy-strategy-france-2018-2020-action-plan .

between biomass supply and demand, and removing regulatory and financial barriers to the sector's growth. This is an interministerial and multi-level approach involving the Ministries of Agriculture, Ecology, Economy, and Research, along with local stakeholders[134].

In accordance with the *European Green Deal* and the strategies mentioned above, particular attention is paid to the need to increase sustainability and circularity in the agri-food sector. This is achieved by exploiting by-products, developing new food processing methods, and using techniques to valorise so-called unavoidable residues, transforming them into biomethane and high-quality fertilisers for soil regeneration. The agri-food sector is therefore the natural meeting point between the bioeconomy and the circular economy, where the sustainability of production processes is combined with food safety and quality.

1.5.5 The Challenge within the Challenge: Circular Economy and Food Sustainability

The scope outlined so far has essentially highlighted three aspects, to be considered as part of concentric circles: the importance of public policy as an agent of change in solving everyday problems, the role of the circular economy as a «tool-objective» of the GDE and the various national strategies on the subject, alongwith the importance of the active involvement of industry as a lever for ecological transition.

[134] At the operational level, a key player is the national cluster Industries & Agro-Resources (IAR), now known as Bioeconomy for Change, which fosters collaboration among businesses, universities, and research centers in green chemistry, biomaterials, biofuels, and the valorization of agricultural residues. The INRAE Institute (Institut national de recherche pour l'agriculture, l'alimentation et l'environnement) serves as the primary scientific center for public research on the bioeconomy, promoting sustainable models of biological resource production and utilization.

Translating these general aspects to a specific context, it is considered appropriate to apply the development paradigm to the agri-food sector. In the author's opinion, aspects typical of both the organic circular economy and the inorganic circular economy are intertwined and mutually reinforcing. On the one hand, the organic component manifests itself in the management and valorisation of biological flows (such as agricultural waste, processing residues, and food by-products). When appropriately reintroduced into production cycles, these flows can generate new value through composting, anaerobic digestion, biogas production, and natural fertilisers. On the other hand, the inorganic dimension of circularity emerges in the rationalisation of industrial processes and the sustainable design of production infrastructure, packaging, and logistics, aimed at minimising the use of raw materials, energy, and water. From this perspective, the agri-food sector is an application of the circular paradigm, promoting hybrid production models that combine the regeneration of biological resources with the conservation of the value of technical materials.

At a doctrinal level[135], the interconnection between the circular economy and food sustainability reflects the now well-established doctrinal thesis that there is no dissociation between the disciplinary sectors of environmental law and food law, but rather a gradual integration[136] .

[135] The link between food sustainability and the circular economy has already found some important references in doctrine. For example, see M.C. RIZZUTO, *La sostenibilità come chiave di sintesi dell'economia circolare*, in S. GARDINI (ed.), *Percorsi di circolarità tra diritto ed economia*, Mucchi Editore, Modena, 2023, pp.125 ff.; N. LUCIFERO, *Economia circolare e prodotti alimentari: l'etichettatura ambientale nel sistema delle fonti di diritto europeo e interno*, in S. GARDINI (a cura di), *Percorsi di circolarità tra diritto ed economia*, *cit*. pp. 91 ff.; S. MANSERVISI, *Il ruolo emergente del diritto agroalimentare e SDGs di Agenda 2030*, in S. CARMIGNANI, N. LUCIFERO (ed), *Le regole di mercato agroalimentare tra sicurezza e concorrenza*, Editoriale Scientifica, Napoli, 2020, pp. 843 ff.

[136] On *this* topic, see M. MONTEDURO, *Alimentazione e ambiente,* in G. ROSSI (ed.), *Diritto dell'ambiente,* Giappichelli, Milano, pp. 352 ff. The author's thesis is based on the idea that

The transition to a sustainable economy proposed by the GDE and supported by the CDI must include the establishment of sustainable food systems that address all stages of the food chain. These are the foundations on which the European Commission's «From Farm to Fork Strategy» is based[137], aiming to propose an integrated agri-food policy - rather than one fragmented into the traditional sectors of agriculture, environment, health, trade, and energy – and to prevent the creation of disjointed rules and interventions[138]. In other words, the objective of this strategy is to completely rethink the conception of food systems: shifting from being the leading cause of harmful climate and environmental externalities to being a potential silver bullet for the transition to climate neutrality and a significant boost to the economic competitiveness of EU countries in this sector[139].

In this context too, the guidelines set out by the circular economy can help to overcome various obstacles hindering the implementation of sustainable and

environmental law should not be seen as a limitation on food law, but rather as a legal discipline that underpins food law, along with the hard sciences, within the multidimensional perspective of the ecosystem-food-sociosystem trinity.

[137] On this point, see the Communication of the European Commission *A 'farm to fork' strategy for a fair, healthy and environmentally friendly food system (*COM), 2020, 381 final.

[138] On this point, reference is made to F. VENTURI, *The farm to fork strategy. A comprehensive but cautious approach to 'multidimensional' food sustainability,* in *RQDA*, 1, 2021, pp. 70 ff. and A. SIMONATO, *Le strategie "dal produttore al consumatore" e per la biodiversità,* in *Aggiornamenti sociali,* 10, 2020, pp. 694 ff. See also, H. SCHEBESTA, M.A. ALESSANDRINI, C. MACCHI, M. J. PLANA CASADO, *Tour de Table: Farm to Fork Update,* in *European Food and Feed Law Review*, 3, 2022, pp. 208 ff.

[139] For a careful examination of the subject, see M. COCCONI, *Sostenibilità dell'accesso al cibo e neutralità climatica: un equilibrio da ricomporre*?, in *Federalismi,* 27, 2023, pp. 1 ff; P. LATTANZI, *Il "Green Deal", la Pac 2021-2027 e la sostenibilità della filiera alimentare*, in P. BORGHI, I. CANFORA, A. DI LAURO, L. RUSSO (a cura di), *Trattato di diritto alimentare italiano e dell'Unione europea*, 2021, pp. 705 ff.

resilient food systems, in which the right to food[140]- recognised as a fundamental human right - is effectively protected. This right, which is closely linked to the principles of dignity, health, and environmental sustainability, requires legal systems to orient production and consumption policies towards models that primarily address the phenomena of food loss and food waste[141].

While *food loss* refers to all losses that occur upstream in the agri-food chain (during sowing, cultivation, harvesting, processing, storage, and initial agricultural processing), the term *food waste* refers to the phenomenon of wasting products that, instead of being used for human consumption, are disposed of, with consequent negative externalities for the environment[142].

As highlighted in the «Food Waste Index Report»[143] *(2024),* 1.05 billion tonnes of food waste were generated in 2022: 132 kilograms *per capita*, 1/5 of the

[140] For an in-depth discussion of the topic, see A. CIERVO, *Il diritto al cibo. Presupposti normativi e precedenti costituzionali di un nuovo diritto fondamentale*, in *Parole-chiave*, II, 2017, pp. 55 ff.; L. COSTATO, *Diritto al cibo*, in *Digesto civ*., XI agg., pp. 165 ff.; L. COSTATO, P. BORGHI, S. RIZZIOLI, V. PAGANIZZA, L. SALVI, *Compendio di diritto alimentare*, CEDAM, Padova, 2022; A. JANNARELLI, *Cibo e diritti. Per un'agricoltura sostenibile*, Giappichelli, Torino, 2015, which highlights the conceptual link between the right to food—in both its individual and collective dimensions—and food sovereignty. For an updated overview, at international, European, and national levels, of the stages of the right to food and its current state of the art, reference is made to M. GALBUSERA, *Cibo, diritti fondamentali e identità nazionale: verso un nuovo valore costituzionale*?, in *Sociologia del diritto*, 2, 2024, pp. 146 ff..

[141] On this point, see C. ELLIOTT, G. BEGER, *From loss and waste to wealth: how industrial innovation can end world hunger*, in *New Food Magazine,* 29 September 2025, available here https://www.newfoodmagazine.com/article/255822/food-loss-and-waste-reduction/

[142] A comprehensive overview of the definitions and global issues surrounding *food waste and loss* can be found in the FAO *Technical Platform on the Measurement and Reduction of Food Loss and Waste* database.

[143] The Food Waste Index Report 2024, compiled by UNEP and WRAP (*The Waste and Resources Action Programme,* a British NGO that works with businesses and individuals to reduce

food available to consumers, 8-10% of annual global greenhouse gas emissions (about five times that of the aviation sector), resulting in global economic damage of approximately $1 trillion.

The key issues, therefore, concern the choice of production methods, the resources to be used, and the management of *outputs*, in constant compliance with food safety and food security standards [144]. In this context, the role of the legal sector is crucial. Summarising the specific requirements mentioned above, the task is to guide food systems towards the pursuit of eco-compatible *milestones*. The objective is not simple and, in many ways, presents critical issues.

Consider the complex and cross-sector issue of reusing agri-food industry production waste in other or subsequent production cycles. While, from a technical perspective, green chemistry proposes several operational solutions, the legal sector still has unclear aspects. Several interpretative uncertainties are linked to the legal category of by-products, which, as highlighted in the introduction, will be the focus of this discussion.

Again, as an example, we refer briefly to the efforts made by legislators to curb the production of food waste[145]. In Italy, reference is made to Law No. 166 of 19 August 2016, concerning the donation and distribution of food and pharmaceutical products for social solidarity and waste reduction. This law shows a recognition of the importance of food sustainability, as it aims to limit the production of negative externalities on the environment, by reducing food waste,

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waste and develop sustainable products), can be consulted here https://www.unep.org/resources/publication/food-waste-index-report-2024

[144] For an in-depth overview of the topic, please refer to L. CALIFANO (ed.), *Sicurezza alimentare, diritto al cibo, etica della sostenibilità. Politiche giuridiche, economiche e sociali,* Franco Angeli, Milano, 2022.

[145] The definition of food waste dates back to 2018, with Directive 2018/815/EU, which classifies food waste as organic waste and defines it as any substance or product intended for human consumption that has become waste because its holder has discarded it or has been instructed to discard it.

and to respond to social solidarity needs[146] . Taking a critical view of this point, however, it should be noted that this law would seem to lead to the paradoxical result of encouraging the production of surpluses to contribute to the food supply of the most disadvantaged sections of the population[147] .

Continuing along these lines, it is also necessary to refer to Regulation 2002/178/EC[148], which establishes the general principles and requirements of food law, and has partially contributed to the exclusion from the market of food products that are simply defective from an aesthetic point of view[149].

Particularly significant is the proposal for a targeted revision of the Waste Framework Directive, presented by the European Commission on 5 July 2023[150]; this proposal aims to introduce binding targets for reducing food waste. According to the text, Member States will be required to promote a 10% reduction in food waste in the food processing and production sectors and a 30% reduction per capita in the distribution, catering, and domestic consumption sectors, compared to the average quantities generated in the three years 2021-2023. In February 2025, the European Parliament and the Council of the European Union reached a provisional

[146] For an in-depth examination, see L. COSTANTINO, *La problematica dello spreco nella filiera agroalimentare. Profili introduttivi*, Cacucci, Bari, 2021; P. LATTANZI, *Le leggi "antispreco" alimentare. Esperienze nazionali a confronto*, in F. DE LEONARDIS (ed), *Studi in tema di economia circolare*, cit, pp. 137 ss.; A. I. TRAPÈ, *Lo spreco alimentare e la legge italiana n. 166/2016*, in *Rivista di Diritto Alimentare*, 2, 2017, pp. 263 ff.

[147] Of this opinion, M.C. RIZZUTO, *La sostenibilità come chiave di sintesi dell'economia circolare*, *in* S. GARDINI *(ed.), Percorsi di circolarità tra diritto e economia, cit.,* p. 142.

[148] Regulation 2002/178/EC lays down the general principles and requirements of food law, establishes the European Food Safety Authority, and lays down procedures in the field of food safety.

[149] M.C. RIZZUTO, *La sostenibilità come chiave di sintesi dell'economia circolare*, *cit., p.* 142.

[150] European Commission, *Proposal for a Directive of the European Parliament and of the Council amending Directive 2008/98/EC on waste,* COM (2023) 420 final, Brussels, 5 July 2023.

political agreement on the revised text[151] , confirming the above objectives. In this sense, therefore, the fight against food waste moves from a mere policy objective to a binding legal obligation and, as a result, reinforces the idea that the circular economy is increasingly becoming a structural regulatory principle.

1.5.6 Governing Circular Agri-Food Systems through the One Health Approach

The application of the circular economy paradigm in the agri-food sector involves an in-depth examination of the One Health approach[152]: an integrated

[151] Council of the European Union, *Council and Parliament agree to reduce food waste and set new rules on waste textiles,* Press release, 19 February 2025, available at: https://www.consilium.europa.eu/en/press/press-releases/2025/02/19/council-and-parliament-agree-to-reduce-food-waste-and-set-new-rules-on-waste-textile/

[152] Interestingly, its evolution is closely linked to a series of global pandemics. In September 2004, at the height of the SARS epidemic, a group of healthcare experts and strategists gathered for the Wildlife Conservation Society's symposium, «Building Interdisciplinary Bridges to Health in a Globalised World». The event focused on the connections between human, domestic animal and wildlife diseases. This symposium resulted in the Manhattan Principles on One World, One Health: twelve recommendations aimed at preventing epidemics and epizootics and preserving the integrity of ecosystems for the benefit of humans, animals, and biodiversity. The central idea was that understanding health and disease phenomena required an integrated approach capable of overcoming disciplinary and sectoral fragmentation by jointly addressing the dimensions of prevention, surveillance, monitoring and environmental conservation. The growth of infectious diseases threatens not only human health and economies, particularly food systems, but also flora and fauna, which are essential for maintaining global biodiversity. For a comprehensive overview of the topic, covering its main stages of development, please refer to G. ANTONELLI, F. PENNA, E. CHATURVEDI, A. CILENTO (eds.), *Planetary Health Laws, Policies and Science on the 'One Health' Approach, Springer,* Cham, 2025; L. VIOLINI (ed), *One Health dal paradigma alle implicazioni giuridiche, Giappichelli,* Torino, 2022; E.SCOTTI *One Health: per un'integrazione tra salute umana*

approach that has become globally recongnised since the 2000s and is endorsed by organisations such as the World Health Organisation (WHO), the Food and Agriculture Organisation of the United Nations (FAO), the World Organisation for Animal Health (OIE) and the United Nations Environment Programme (UNEP).

By expressing a unified and integrated vision of humans, animals, and the environment, the One Health approach highlights the interdependence between natural systems and human activities and places among its most urgent needs to push the governance and regulation of the agri-food sector towards this paradigm[153].

From this perspective, the circular economy in the agri-food sector is not only a strategy for improving process efficiency, but also as a genuine component of a broader system for preventing health, ecological, and socio-economic risks. Indeed, the recovery and regeneration of biological resources, the reduction of waste, and the valorisation of agro-industrial by-products are fundamental tools for implementing this approach, for example, by reducing the environmental impact of production cycles, preserving soil and water quality, and limiting the spread of pathogens in the supply chain.

Increasingly, therefore, the challenge of food sustainability, in its cross-cutting and extraterritorial dimension, requires the various sciences involved to develop a synergy aimed at pursuing coordinated and comprehensive solutions immediately. The legal field represents the collector of this synergy, or, in other words, the means by which the results achieved by the hard sciences can be

e ambientale, in F. APERIO BELLA (ed), *One Health: la tutela della salute oltre i confini nazionali e disciplinari,* Editoriale Scientifica, Napoli, 2022 pp. 45 ff.

[153] For relevant contributions in the literature, see, for example S. PITTO, *Cambiamento climatico e sicurezza alimentare: dall'approccio One Health ai modelli olistici del Global South*, in *BioLaw Journal - Rivista Di BioDiritto,* 2, 2023, pp. 315 ff; M. LEGGIO, A.G. CARAGLI, *Governance e regolazione del settore agroalimentare verso il paradigma One Health*, Giappichelli, Torino, 2024.

translated into efficient public policies[154]. In this regard, Regulation 2002/178/EC established the European Food Safety Authority (EFSA). Regarding this, it is essential to reiterate how EFSA contributes to the synchronisation of technical and scientific risk assessments (and risk management) related to food safety and public policy decisions[155], acting as a link and harmonizer among the scientific community and policy-makers. This demonstrates that the One Health approach is not merely

[154] For an up-to-date and in-depth analysis of these challenges translated into legal language, please refer to L. SCAFFARDI, V. ZENO-ZENCOVICH, *Cibo e diritto. Una prospettiva comparata,* Vol. 1, RomaTre Press, Roma, 2020 and L. COSTATO, F. ALBISINNI, T. GEORGOPOLOUS (eds.), *European and global food law,* CEDAM, Padova, 2025.

[155] *Funditus,* on this topic, see M. COCCONI, *The balance between technique and policy in the public decision-making process: the EFSA case (European Food Safety Authority),* in *RQDA,* 3, 2020, pp. 233 ff. In particular, on p. 236, the author states that «Public decisions in the food safety sector are the final outcome of a risk analysis procedure with a composite structure in which the risk management phase, which is the responsibility of the European Commission, is always preceded by a risk assessment phase; it is an essentially scientific evaluation, consisting of assessments and technical assessments, entrusted to the European Food Safety Authority (hereinafter, EFSA). The achievement of the function ('the general objective of a high level of protection of human life and health', in Article 6 of the Regulation) is ensured by the articulation of the procedure through the dual phases of the analysis. The ability of this procedure to perform its function is related to the coordination between these phases and between the authorities responsible for carrying out the related activities. As stated in recital 36 of the established regulation, "to ensure greater coherence between the risk assessment, management and communication functions, a closer link should be created between those responsible for risk assessment and those responsible for risk management". The same coordination between the actors involved was evoked by art. 22, paragraph 8: "The Authority, the Commission and the Member States shall collaborate to promote effective coherence between the risk assessment, risk management and risk communication functions". The choice of the European legislator, in fact, since the establishment, in Regulation No. 178 of 20026, had been that of not delineating EFSA as an effective regulatory Authority, i.e. with real decision-making powers in the proper sense but with a prevalent function of scientific advice and assessment, legitimised by high expertise and adequate organisational features to fulfil this role. As emerges, in effect, from art. 6 of Reg. No. 178/2002: "The risk assessment is based on the scientific evidence available and is carried out in an independent, objective and transparent way"».

theoretical, but translates into institutional and regulatory practices that aim to influence the entire European food *governance system*.

From this perspective, the transition to circular models in the agri-food sector not only promotes supply chain efficiency, but also fosters the development of new tools - including legal measures - capable of incorporating health and environmental risk management within a *blue economy* framework.

The coordinates developed in this chapter are intended to outline the interpretative framework within which the dogmatic analysis developed in the following chapter is situated. The concepts of complexity, transition and circularity find concrete application in European and national legislation on waste, end-of-waste and by-products, in full compliance with the dynamics of transformative law. The transition to the analysis of positive law makes it possible to verify the extent to which the current regulatory framework can translate the objectives of the ecological transition into operational legal instruments, as well as to identify the main interpretative and applicative critical issues that hinder the full integration of by-products into the circular economy. In this sense, the second chapter represents a test bed for the theoretical premises, showing how the dynamics of complexity and regulatory fragmentation are reflected in the concrete legal classification of material flows.

Chapter 2: By-Products in the Circular Economy. Legal Framework and Governance Challenges

2. Waste, *End of Waste* and by-products: an Overview of the European and Italian Dimensions

2.1. Rethinking the Legal Definition of Waste in the Context of Circularity

Because these statements require concrete examples, the discussion focuses on a significant challenge that may hinder the development of an effective circular food economy: managing food industry production waste. As explained in the introduction, these substances are at a crucial juncture, determined by a key question and focused on different possibilities for their legal classification.

Before defining the specific case of production waste management in the agri-food system, it is necessary to outline the general legal framework that governs the distinction between waste, by-products and the End of Waste (EoW) regulations. This should offer an integrated European perspective, taking into account the specific issues involved in transposing these regulations into Italian law.

The latest waste management regulations are outlined in Framework Directive 2008/98/EC, later amended by Directive 2018/851/EU[156], and incorporated into Part IV of the Italian Environmental Code through Legislative Decree 116/2020.

[156] This directive, known as the "waste directive", is part of the Circular Economy package published in the Official Journal of the European Union on 14 June 2018. The package also includes Directive 849/2018/EU (the so-called vehicle, battery, and WEEE directive), Directive 850/2018/EU (the so-called landfill directive), and Directive 852/2018/EU (the so-called packaging directive). For an in-depth analysis on the subject, see M. COCCONI, *La regolazione dell'economia circolare, cit.,* pp. 42 ff. and S. ANTONIAZZI, *Transition to the Circular Economy and Services of General Economic Interest,* in *Federalismi, 7,* 2021, pp. 1 ff.

Taking up the uniform definition, Article 183, paragraph I, letter a) of the Italian Environmental Code[157] defines waste[158] as «any substance which the holder discards or is required to discard».

The concise nature of this definition has led to a extensive and dynamic body of case law from the Court of Justice of the European Union[159], which has frequently underscored the importance of interpreting waste broadly, because of the main goal of safeguarding human health and the environment within the regulatory framework established by the European Union.

In particular, significant interpretation challenges have been linked to clarifying the term "discard", which was originally extended to any object or substance the owner discards, regardless of its commercial value or potential for

[157] The latter reports what was initially provided for by Legislative Decree 22/1997 and Directive 2006/12/EC.

[158] *Ex multis,* among scholars, see F. DE LEONARDIS, *I rifiuti: da "problema a risorsa),* in G. ROSSI (ed.), *Diritto dell'ambiente,* Giappichelli Editore, Torino, 2021, pp. 324 ff.; M.F. TOMMASINI, *La fenomenologia del rifiuto tra atti di dismissione e tutela del bene ambiente,* in *Contratto e Impresa,* 2018, pp. 416 ff.; C. FELIZIANI, *La gestione dei rifiuti in Europa,* in Federalismi, 15, 2017, pp. 1 ff; R. AGNOLETTO, *La gestione dei rifiuti,* in R. FERRARA, M.A. SANDULLI (eds..), *Trattato di diritto dell'ambiente,* Giuffrè, Milan, 2014, pp. 443 ff.; F. PERES, *Rifiuti,* in A.L. DE CESARIS, S. NESPOR (eds..), *Codice dell'ambiente,* Giuffrè, Milan, 2011, pp. 165 ff.; P. DELL'ANNO, *Rifiuti,* in S. CASSESE (ed.), *Dizionario di Diritto Pubblico,* V, Giuffrè, Milan, 2006, 5032 ff.; ID., *Disciplina della gestione dei rifiuti,* in E. PICOZZA, P. DELL'ANNO (eds..), *Trattato di Diritto dell'Ambiente,* CEDAM, Padova, 2013, pp. 201 ff.; G. BELLOMO, *Disfarsi… o non disfarsi… questo è il problema: la Corte aggiunge un'altra «pietra» sulla via della nozione di rifiuto e dei relativi criteri di individuazione,* in *Diritto pubblico comparato europeo,* 2002, pp. 1311 ff.; G. PAGLIARI, *La nozione giuridica di rifiuto,* in *Rivista giuridica dell' Urbanistica,* 2002, pp. 95 ff; F. BASSI, *Sul concetto giuridico di rifiuto,* in *Rivista Giuridica dell' Ambiente,* 1988, pp. 47 ff.

[159] CJEU, 15 June 2000, C-418/97 and C-419/97.

recycling or reuse[160]. The national court has also been questioning the proper definition of waste for years[161] .

The Italian Supreme Court has clarified that any subjective judgment about whether materials are waste is unacceptable. Waste is not simply what the holder no longer finds useful based on personal preference, but rather what can be objectively classified as waste according to specific data on the holder's actions or legal obligations. This includes the requirement to dispose of the material as previously described[162]. Currently, therefore, the Italian Court of Cassation identifies waste solely based on objective findings.

Today, waste management follows a clear hierarchy where prevention is key[163] : the main goal is to avoid creating waste, mainly by using various tools to guide the business world towards eco-design[164] .

In this context, extended producer responsibility (EPR)[165] is an innovative approach aimed at discouraging the production of short-lived waste. Producers are mandated to cover the costs associated with their products' end-of-life, acknowledging the negative environmental impact. Holding producers responsible for a product's entire lifecycle, including post-consumer stages, is a powerful tool to promote more sustainable production strategies[166]. For example, in the packaging

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[160] In particular, see CJEU, 28 March 1990, C-206/88 and C-207/88 Zanetti and CJEU, 25 June 1997, C-304/94 *Trombesi.*

[161] *Among others,* see Italian Criminal Court of Cassation, 16 November 2016, n. 48316**.**

[162] *Ibidem.*

[163] See Article 179 of the Italian Environmental Code.

[164] Reference is made to F. DE LEONARDIS, *I rifiuti: da "problema a risorsa", cit.*, pp. 339 ff.

[165] At the European level, the E.P.R. is regulated by Articles 8 and 8-bis of Directive 2008/98/EC, as amended by Directive 2018/851/EU. At the national level, it is governed by Articles 178-bis and 178-ter of the Environmental Code instead.

[166] Among the numerous doctrinal sources on the point, the reference is to N. GRANATO, *Economia circolare e Responsabilità estesa al produttore: una strategia di politica ambientale*, in

industry, producers may pay varying contributions based on whether the materials they use are recyclable or not[167] .

In the current system waste, management is a necessary step, when the formation of output cannot be avoided. In turn, waste management involves specific processes.

Whenever possible, waste should be reused without extensive treatment. If reuse isn't feasible, waste management moves toward recycling to produce a uniform raw material. If recycling isn't an option, the waste can undergo recovery activities, often aiming to convert it into fuel. Disposal in landfills is considered the last resort[168] .

M. COCCONI (ed.) il *Mosaico dell'economia circolare. Regole Principi, Modelli, cit.,* pp. 69 ff; F. DE LEONARDIS, *La regolazione ambientale tra fondamenti costituzionali, "standards di circolarità" e sistemi di extended producer responsibility* (EPR), in *Diritto Amministrativo e Società Civile*, Bononia University Press, 2020, Vol. 3, pp. 579 ff.; C. DALHAMMAR, *Extended Producer Responsibility,* in L. KRÄMER, E. ORLANDO (eds..), *Principles of Environmental Law*, *Elgar Encyclopedia of Environmental Law*, VI, 2018, pp. 210 ff.; G. AMENDOLA, *La responsabilità estesa del produttore quale asse portante dell'economia circolare nella normativa comunitaria e nel d.lgs. n. 116/2020*, in *Diritto e giurisprudenza agraria, alimentare e dell'ambiente*, 1, 2021, pp. 1 ff.; A. SCARCELLA, *Con le modifiche alla parte quarta del testo unico la normativa di settore cambia forma e contenuti. Responsabilità estesa a carico del produttore,* in *Guida al Diritto - Dossier*, 1, 2011, pp. 77 ff.

[167] Specifically, this refers to the CONAI environmental contribution, known as C.A.C. Interesting insights on this topic are provided by Laboratorio REF-Ricerche. This think tank brings together representatives from the worlds of business, institutions, and finance in order to foster debate on the future of local public services. In particular, see Laboratorio REF-Ricerche, contribution number 137, *La responsabilità estesa del produttore (EPR): una riforma per favorire prevenzione e riciclo,* January 2020.

[168] See, F. DE LEONARDIS, *I rifiuti: "da problema a risorsa", cit.*, pp. 335 ff.

Proper waste management relies on an efficient traceability system[169]. Recently, as part of the National Waste Management Plan (PNGR) approved in June 2022, a new waste traceability system was introduced to replace the criticized S.I.S.T.R.I. system. This new system, called R.E.N.T.R.I. (National Electronic Register for Waste Traceability), is currently in its experimental phase[170]. The latter aims to implement a new operational scheme for waste traceability by replacing current paper-based requirements with updated digital versions. Data related to waste management should become more accessible and easier to understand, reducing the administrative and bureaucratic burdens on businesses.

Currently, besides various efforts at "upstream" prevention - mainly encompassed by the eco-design principle - there is notable progress in "downstream" prevention, which focuses on removing all reusable goods and substances from waste, while safeguarding human health and the environment.
Overall, the current legislation is noticeably more progressive than it was a few years ago, when the "total waste party" played a dominant role[171] .

[169] It specifically refers to Ministerial Decree 257/2022. The text is an integral part of Article 198-bis of the Environmental Code, which covers the period from 2022 to 2028, and must be updated at least every six years. This legislative measure is part of Mission 2 of the National Recovery and Resilience Plan (NRRP).

[170] The R.E.N.T.R.I. was introduced with Legislative Decree No. 116/2020; once it becomes operational, it will definitively replace the paper-based waste tracking system, specifically regarding the Load and Unload Register and the FIR.

[171] It is worth recalling that Directive 75/442/EEC stated that waste management, in essence, should be based on their disposal (alternatively between landfill and incineration). In order to speak of strategic recovery of waste, we will have to wait for Directive 91/156/EEC.

Until the early 2000s, EU case law[172] (fully supported by the Italian Constitutional Court[173]) generally interpreted waste broadly, often at the expense of the end-of-waste and by-products categories. As explained below, later case law has shown a more open stance on this issue.

2.2 End of Waste the Bridge between Waste and Resource

The term *End of Waste* refers to specific recovery processes by which waste becomes a product *tout court*[174] . Implementing Article 6 of Directive 2008/98/EC, Article *184-ter*, paragraph I, letters a) to d) of the Environmental Code make this transformation subject to certain cumulative conditions.

Firstly, the substance or object must be commonly used for specific purposes; this means that «it must be a widely used product, capable of performing

[172] See the judgment of the CJEU, 28 March 1990, C-359/88, *Zanetti, cit.*; *idem,* 10 May 1995, case C-442/1992, *European Commission/Germany* in the EUR-Lex database; *idem,* 15 June 2000, C-418/97, *Arco.*

[173] Italian Constitutional Court, 28 January 2010, no. 28; as reported by R. LEONARDI, *La qualifica dei residui di produzione ai sensi del decreto ministeriale N. 264/2016: rifiuti o sottoprodotti,* in *Rivista Giuridica dell'Edilizia,* 3, 2017, pp. 91 ff, «the Constitutional Court has established some definitive interpretative points: a) the notion of waste must be understood in an extensive sense, and in this way, the provisions that refer to it must be interpreted; b) substances and products susceptible to economic use are excluded from this notion, in cases where they are not products that the holder disposes of; c) by this notion, by-products are not included, understood as goods, materials, or raw materials that derive from an extraction process or fabrication, that is not primarily intended to produce them, provided that their use is certain and not merely potential, without preliminary transformations and for the purpose of commercialising the material, even possibly to be destined for subjects other than the producer». (free translation)

[174] S. MAGLIA, P. PIPERE, L. PRATI, L. BENEDUSI, *Gestione ambientale. Manuale di diritto e gestione dell'ambiente,* Edizioni Tuttambiente, Piacenza, 2021, pp. 192 ff.; D. IACOVELLI, *Dal rifiuto all'End of Waste,* in *Il Diritto dell'Economia,* 1, 2019, pp. 193 ff.

known and defined functions»[175] . Furthermore, waste can only be transformed if the substance or object has a market presence and can meet the technical requirements, regulations and, existing *standards* required for that particular product. Finally, the admissibility of this transformation process depends on the absence of any negative impact on the environment or human health.

Through various regulations, the European Union established specific criteria for the end-of-waste status; reference is made, in particular, to copper scrap[176] , glass[177] and iron, steel and aluminium[178] . These have been followed - at the national level - by several ministerial decrees relating to additional categories[179] . For example, reference is made to the Ministerial Decree 152/2022, which regulates the end-of-waste status of inert construction and demolition waste, as well as other inert mineral waste[180] . Specifically, this refers to solid waste which, by its nature, is not subject to physical, chemical, or biological alterations; it falls within the category of special waste and, subject to the limits imposed by current legislation, can be given a second life in so-called recovered aggregates.

The regulation in question crosses the regulatory landscape with a particularly uncertain step, given the application issues that arise. Although, on the one hand, the ministerial decree imposes an obligation to comply with these requirements within 180 days of its entry into force[181] , on the other hand, it allows

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[175] *Ibid.* p. 193.

[176] See Regulation 2013/715/EU.

[177] See Regulation 2012/1179/EU.

[178] See Regulation 2011/333/EU.

[179] For example, consider Ministerial Decree 22/2013 on CSS-Fuel, Ministerial Decree 78/2020 on vulcanised rubber, Ministerial Decree 118/2020 on paper and cardboard, and the very recent Ministerial Decree 152/2022 on inert waste from construction and demolition, as well as other inert waste of mineral origin.

[180] *Funditus,* see P. PIPERE, *End of Waste e rifiuti inerti. Nuovo decreto e annunciate criticità*, in *Tuttambiente.it,* 7 November 2022.

[181] See art. 8 D.M. 152/2022.

for the possibility that the Ministry of the Environment and Energy Security[182] may assess the appropriateness of revising the criteria for the end-of-waste status of these substances, «in order to take into account, where necessary, the evidence that has emerged during the application phase». [183]

The Council of State[184] stresses the importance of approaching the recovery of waste that may affect human health and the environment with great caution. It also emphasizes that the Administration must carefully evaluate how these prudential limits impact the effectiveness of the circular economy mechanism introduced by this regulation, to prevent a substantial decrease in the amount of such waste actually sent for recovery[185] . However, the leading trade associations in the sector[186] have reported that the implementation of the new regulations has led to a significant and unjustified decrease in the ability to reuse inert waste compared to the European reference framework.

Undoubtedly, the issue becomes especially significant at this moment in history, marked by the essential role of the State in supporting the recovery of the construction market through the “Superbonus”[187].

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[182] Note that the text of the Ministerial Decree (D.M.) includes the wording, adopted during the Draghi Government, of the Ministry for Ecological Transition.

[183] See art. 7 D.M. 152/2022.

[184] In fact, see the advisory opinion of the Council of State no. 851/2022, reported on the ANPAR website (National Association of Recycled Aggregate Producers).

[185] *Ibidem*, p. XVI.

[186]The reference, in particular, is to the note of 29 June 2022, signed jointly by ANPAR (Assoambiente), ANEPLA (National Association of Stone Extractors, Producers, and Related Industries), and Nadeco (National Association for Demolition and Circular Economy for Construction).

[187] The reference relates to the so-called 'Super Bonus 110%', a particular tax relief provided for in Article 119 of Decree Law No. 34/2020, known as the 'Relaunch Decree', which allowed a deduction of 110% of expenses incurred from 1 July 2020 for interventions aimed at energy efficiency, static consolidation, or seismic risk reduction of buildings. As is well known, with Law

In fact, the extensive renovation work currently underway on many buildings is causing a significant rise in inert waste, and only through a comprehensive circularity model can most of this waste be prevented from ending up in landfills. These dynamics reflect a complex reality and emphasize the challenge—which has always been tied to waste management—of balancing health protection with the need to develop sustainable models.

This brief aside allows us to focus on the possibility for each Member State to intervene at the regulatory level regarding the subject of End of Waste. This point is confirmed in Directive 2008/98/EC, Article 6, paragraph IV, which states that, in the absence of specific EU criteria, each Member State has the option to define, on a case-by-case basis, specific criteria for the end-of-waste status.

A key decision by the Council of State[188] focused on how this provision is understood. The judges at Palazzo Spada took a very literal and restrictive view of Article 6 of the directive mentioned earlier. They ruled that, unless specifically referenced by the Community, the responsibility for setting the criteria for end-of-waste status lies exclusively with the State, not with its internal agencies or organizations[189] .

6/2023, which converted Decree Law 176/2022, the so-called Quater Aid Decree, the deductibility of the aforementioned expenses was reduced to 90% for the year 2023.

[188] See the judgment of the Italian Council of State 1229/2018, in *Rivista giuridica* dell'ambiente, 2018, pp. 374 ff., commented by R. GUBELLO, *La Regione non può decidere quando un rifiuto non è un rifiuto.* See also A. MURATORI, *Una doccia fredda dal Consiglio di Stato sulla competenza delle Regioni a sancire l'end of waste mediante provvedimenti autorizzativi,* in *Ambiente e sviluppo,* 2018, pp. 225 ff.

[189] *Ibidem:* «In light of the provisions outlined above, it can, therefore, be stated that, in general, the regulation of the cessation of the status of "waste" is reserved to Community law; nonetheless, this has allowed that, in the absence of specific provisions, Member States may assess on a case-by-case basis the possible cessation – repeated, only in the absence of Community guidance and, therefore, not in conflict with it – and inform the Commission accordingly. The recipient of the power to determine the cessation of waste status is, for the directive, the 'State',

The authoritative doctrine[190] described the Council of State's ruling as fundamentally opposed to constitutional case law[191], which, regarding health protection, acknowledged the constitutional role of the Region's authority in waste disposal. This reasoning was grounded in the principle of subsidiarity, as outlined in Articles 117, first and third paragraphs, and 118, paragraph I, of the Constitution, along with Article 3-quinquies, paragraph III, of the Environmental Code. The Constitutional Court's perspective might also be relevant to End of Waste procedures, as these waste transformation processes are strictly regulated by the requirement to avoid negative impacts on human health.

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which also has an obligation to engage with the Commission. The same EU directive, therefore, does not recognise the power of 'case-by-case' assessment to entities and/or organisations within the State, but only to the State itself, since such assessment can only reasonably take place, if not with reference to the entire territory of a Member State». (free translation)

[190] S. MAGLIA, P. PIPERE, L. PRATI, L. BENEDUSI, *cit.*, pp. 199 ff.

[191] Specifically, see the Judgment of the Constitutional Court, 75/2017. The latter, in fact, declared the constitutional illegitimacy of Article 49 of Law 221/2015, which contains provisions concerning the green economy and the containment of natural resource use. The Italian Constitutional Court stated that «the connection between environmental regulation, particularly waste management, and health protection is undisputed, as evidenced by the jurisprudence of this Court (judgments no. 58 of 2015, no. 244 of 2012, no. 373 of 2010, no. 249, no. 225 and no. 61 of 2009, no. 62 of 2008), Directive 2008/98/EC (see the preamble and, in particular, Articles 1, 12, 13, and 17), and the Environmental Code (see, in particular, Articles 177, 179, 182-bis, 191, and 208, paragraph 1). Additionally, the regulatory function of regions concerning waste treatment, which is now excluded from the contested norm for some instances, must be recognised as having constitutional rank, since Article 208 of Legislative Decree no. 152 of 2006, which assigns this function to the regions, applies the principle of subsidiarity set out in Article 118, first paragraph, of the Constitution, reaffirmed explicitly for environmental matters by Article 3-quinquies, paragraph 3, of the Environmental Code. A violation of the directive thus also results in the indirect infringement of the constitutional administrative autonomy guaranteed to the Region. Therefore, the unconstitutionality of Article 49 of Law no. 221 of 2015 must be declared, due to a violation of Articles 117, first and third paragraphs, and 118, first paragraph of the Constitution» (free translation)

In accordance with the Council of State's ruling, several amendments[192] were made to Article 184-ter, paragraph III, of the Italian Environmental Code[193]. In the absence of specific criteria on this matter at the European or national ministerial level, the requirements for waste recovery are set out in the authorisation procedures detailed in Articles 208 et seq. of Legislative Decree 152/2006. These procedures are subject to the mandatory and binding opinion of ISPRA or the relevant regional environmental protection agency.[194].

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[192] These are described in detail by S. MAGLIA, P. PIPERE, L. PRATI, L. BENEDUSI, *cit.*, pp. 200 ff. Stimulating regulatory reform on this matter was the Contarina case law, which involved Contarina S.p.A. (an in-house company responsible for waste disposal and collection) opposing the Veneto Region. The S.p.A. had developed an experimental waste recovery plant for nappies and sanitary pads; after the trial period, the S.p.A. requested an EoW (End of Waste) authorisation based on a case-by-case approach. Contarina challenged the refusal before the Veneto Regional Administrative Court (TAR Veneto): the court stated, also considering a circular from the Ministry of the Environment, that it was instead possible to issue an atypical authorisation, even in the absence of European or national criteria. The first-instance ruling was, however, overturned by the Council of State, which held that the directive entrusted the assessment task solely to the State, and not through a permit for a single plant but for waste types in general terms (i.e., not through specific acts, but through a general act). The legal system responded quickly, promptly rewriting the procedure for issuing case-by-case authorisations. Notable jurisprudence examples include TAR Veneto 1422/2016 and the Council of State 1229/2018. For a broader reconstruction that relates the role of EoW in the technological innovation process, see G. BIASUTTI, *Innovazione e diritto ambientale: il caso dell'*End of Waste, in S. GARDINI (ed.), *Percorsi di circolarità tra diritto ed economia,* Mucchi Editore, Modena, 2023, pp. 27 ff.

[193] D. ROTTGEN, *È arrivata la conferma per l'End of Waste tramite provvedimenti autorizzatori,* in *Ambiente e sviluppo.* 2016, pp. 632 ff.

[194] Furthermore*,* G. BAROZZI REGGIANI, *Ambiente rifiuti, principio di Legalità: obiettivo endo of waste* in *Federalismi,* 4, 2018; at p. 11, the author clarifies how «A different discussion must instead be conducted in relation to the so-called "simplified" procedures, regulated by Article 214 et seq. of the Consolidated Environmental Act [...] The reference made by paragraph three of Article 184-ter to Ministerial Decree of 5 February 1998 (as well as to decrees of 12 June 2002, no. 161 and 17 November 2005, no. 269) has the effect of binding the discretionary activity of the competent

Although a clear boundary exists between waste and end-of-waste, established through a strict authorization system, the connection between these categories and by-products is less defined. In fact, by-products occupy a grey area, both in terms of their definitions and regulatory treatment.

2.3 By-products as the Cornerstone of Circular Resource Regulation

Proceeding step by step, it is appropriate to shift the spotlight to the genesis of the concept of by-products[195] , which unquestionably takes shape within a mobile jurisprudential matrix. After years of operating under the belief that all production waste should be classified as waste, the beginning of the new millennium marked a clear reversal on this issue.

Administrations (the Provinces, in this case) to issue the authorisation for carrying out waste recovery activities (including for EOW purposes) according to the simplified procedure outlined in the same ministerial decrees, whose scope of application cannot be considered extended to the ordinary authorisation procedures referred to in articles 208 et seq. of the Consolidated Environmental Act and to procedures aimed at issuing the Integrated Environmental Authorisation» (free translation); see also G. BIASUTTI, *Autorizzazioni ambientali ed End of Waste. Tra procedimenti amministrativi sui generis e garanzie in favore del privato,* in *Federalismi,* 29, 2020, pp. 17 ff.

[195] Regarding this topic, there are multiple doctrinal studies. See R. LEONARDI, *op. cit.* pp. 94 ff.; E. POMINI,*Il punto sui sottoprodotti: la certezza del riutilizzo,* in *Rivista Giuridica dell'Ambiente,* 6, 2012, pp. 753 ff.; F. VANETTI, *Terre e rocce da scavo e altri materiali: rifiuti o sottoprodotti?,* in *Rivista Giuridica dell'Ambiente,* 6, 2011, pp. 803 ff.; D. FRANZIN, *La Corte costituzionale e la definizione di rifiuto: nuovo capitolo di una complessa vicenda di illegittimità comunitaria,* in *Cassazione Penale,* 2011, 1, pp. 117 ff.; G. LAGEARD, M. GEBBIA, *soluzione "sottoprodotto": scelta a rischio di contestazione per il produttore del residuo,* in *Ambiente e Sviluppo,* 2011, pp. 10 ff.; S. ANILE, *Rifiuti, sottoprodotti e Mps: commento ai nuovi articoli 184-bs e 185-ter,* in *Rifiuti,* 2011, pp. 38 ff.; L. RANACCI, *I sottoprodotti all'esame della Corte costituzionale,* in *Giurisprudenza di Merito,* 2007, pp. 1088 ff.

In the *Palin Granit* ruling[196] , the Court of Justice of the European Union initially distinguished waste and production residues, identifying the latter as secondary substances that, although not serving the main production purpose, can be marketed and exploited. Originally, case law[197] deemed it reasonable to exclude substances that had undergone preliminary treatment or been reused in production processes other than the original one from being identified as by-products. However, over the years, the concept of a by-product has expanded to encompass significant connotations of openness.

The recognition of the concept of by-product in case law has undoubtedly guided European and national lawmakers. The European legislator introduced the concept of by-products with Directive 98/2008/EC (which was subsequently amended by Article 5(5) of Directive 2018/851/EU[198]).

The directive has been incorporated into Italian legislation via Article 184-bis, paragraph 1, of the Environmental Code[199]. Consequently, the latter stipulates the precise criteria that must be fulfilled for a specific production residue to be designated a by-product.

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[196] CJEU Judgment, 18 April 2022, C-9/00.

[197] On this point, see CJEU, 11 November 2004, C-457/02, *Niselli,* in *Rivista di Diritto dell'Ambiente,* 2005, pp. 275 ff., and CJEU, 11 September 2003, C-114/01, *Avesta Polarit ChRoma,* in *Rivista di Diritto dell'Ambiente,* 2003, pp. 995 ff.

[198] The novelty introduced by this directive consists in the fact that the conditions for qualification as a by-product, as set out in Article 5, must necessarily be met. Furthermore, a specific provision has been introduced whereby, through ad hoc implementing acts, detailed criteria can be established for the uniform application of conditions to particular substances or objects. On this topic, see M. COCCONI, *La regolazione dell'economia circolare, cit.*, pp. 44 ff. Recently, the Court of Luxembourg issued a ruling providing a significant interpretation of the Community position on the issue. See CJEU 17 November 2022, case C-238/21, *Porr Bau.*

[199] Inserted into the Environmental Code by virtue of Article 12 of Legislative Decree 205/2010.

Firstly, it is imperative to ascertain that the substance in question has its provenance in a production process that is principally concerned with the generation of another primary substance. Furthermore, the secondary substance is required to be reused and undergo only standard industrial processing. It is evident that the utilisation of the by-product must be in accordance with the prevailing legal framework and adhere to all technical standards that have been meticulously designed to ensure the preservation of public health and the integrity of the environment.

Failing to meet any of the criteria mentioned results in the material being classified as waste, which then requires the implementation of strict "End of Waste" regulations for its reuse.

As can be readily inferred, the notion of by-products entails a certain degree of intricacy and a number of pivotal considerations. Despite the evident environmental and economic advantages of by-products, including the reduction of waste, conservation of raw materials and potential savings for businesses, there are significant interpretative difficulties and regulatory gaps.

To address these issues systematically, it is necessary to map them out, starting with the general rules governing by-products and then focusing on additional critical issues related to specific subcategories, such as agri-food.

2.4 Critical Aspects in the Italian Regulation and Practice of By-Products

2.4.1 The Uncertain Boundaries of Normal Industrial Practice

Firstly, the requirement to treat things according to "normal industrial practice" has created several uncertainties in how it is applied. Determining the difference between normal and non-normal industrial practice for any specific production activity is not easy.

Legal scholars have pointed out that this criterion is too vague and arbitrary[200] , while the Supreme Court has attempted to clarify this phrase with content through an initial *case-by-case* identification[201] , and later efforts to create concise definitions.

In 2012[202] , the Italian Supreme Court of *Cassazione* excluded from the concept of normal industrial practice all activities «involving radical transformations of the treated material that alter its original nature, as well as all manipulative interventions on the residue other than those normally carried out in the production process in which it is used». This definition was interpreted by legal scholars[203] as completely misleading and contradictory, given the non-automatic link between radical transformations of the product and their non-ordinariness. In

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[200] F. GIAMPIETRO, A. MURATORI, D. ROTTGEN, *Il D. Lg. n. 205/2010 sui rifiuti: prima lettura,* in *Ambiente e Sviluppo,* 2, 2001, pp. 105 ff.

[201] For example, see Italian Criminal Court, judgment 40109/2015.

[202] On this point, see Italian Criminal Court, judgment 17453/2012.

[203] See S. MAGLIA, *Normale pratica industriale: la contraddittoria e "pericolosa" interpretazione della Cassazione (nota a Cass. No. 17453/2012)*, in *Ambiente e Sviluppo,* 7, 2012, pp. 611 ff.; A. MURATORI, *Sottoprodotti: la Suprema Corte in difesa del sistema Tolematico? (nota a Cass. no. 17453/2012)*, *ibid.,* pp. 605 ff. L. PRATI, *Rifiuto, sottoprodotto e normale pratica industriale:necessità di una interpretazione che tenga conto della finalità della norma,* in *Lexambiente.it.,* 29 may 2013.

these terms, normal industrial practice would be limited to minimal interventions, thereby losing opportunities to reuse production waste.

Just one year later, the judges developed a more flexible definition, according to which normal industrial practice should be considered to be «the series of operations that the company normally carries out on the raw material that the by-product replaces, thus excluding all manipulations of the residue that are different from those normally carried out in the production process in which it is used»[204] .

Ministerial Decree 264/2016 aimed to define the concept of normal industrial practice, with the goal of clarifying and specifying criteria for classifying production residues as by-products rather than waste. Although it tried to resolve interpretative issues related to by-product regulations, the decree actually increased uncertainties. As a result, a few months later, the Ministry of the Environment issued an explanatory circular[205] .

The definition provided by the ministerial decree in question[206] recognises as standard industrial practices the treatments needed to make the residue suitable

[204] See Italian Criminal Court of Cassation, judgment 20886/2013.

[205] See Circular 30 May 2017, ref. no. 7619 from the Ministry of the Environment and Protection of Land and Sea, which begins as follows: «In consideration of the numerous questions received by this Ministry regarding various interpretative and operational aspects, it seems useful to provide some clarifications here, to enable a uniform application and a consistent interpretation of the measure. Given the objective complexity of the regulation, of both internal and European origin, concerning the use of by-products, and the lack of long-established interpretative practices, it is deemed helpful to provide some interpretative clarifications to facilitate better application of the decree, accompanied by a technical-legal Annex, which must be considered an integral part thereof.» (free translation)

[206] Article 5, paragraph 1, of D.M. 264/2016 states that processes and operations necessary to render the environmental characteristics of the substance or object suitable to meet, for the specific use, all relevant requirements concerning products and the protection of health and the environment, and to avoid overall negative impacts on the environment, do not constitute normal industrial practice," unless they are carried out within the same production cycle, in accordance with paragraph 2. Paragraph 2 follows: "In any case, activities and operations that are an integral part of the residue

for its specific use, in full respect of health and the environment; however, these treatments must be an integral part of the production cycle for the manufacture of the main products[207] . It is obvious that this statement will inevitably lead to concrete uncertainties in its application.

Nevertheless, the task assigned to the regulation in question is to find a delicate balance: on one hand, to prevent the management of actual waste without the necessary precautions and authorizations, and on the other hand, to support the practical implementation of a circularity model, fully aware that, like any raw material, a by-product may also need preliminary processing before its use.

A case-by-case review and systematization of similar production cycles could help clarify the concept of normal industrial practice The challenge lies in creating a legal definition that is both precise and specific, yet flexible enough to encompass technological innovations relating to improvements in industrial processes and purpose-built facilities. Currently, the concept of normal industrial practice is still subject to a rigid interpretation.

2.4.2 Regulatory Uncertainty and Its Distorting Effects from Uncertain Legal Use to Disguised Illegal Practices

The peculiarity that sets the regulation of by-products apart from waste management is that using by-products does not require any authorization process typical of administrative law.

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production cycle, even if designed and carried out specifically to make the environmental or health characteristics of the substance or object suitable to enable and promote, for the specific use, all relevant requirements concerning products and the protection of health and the environment, and to avoid overall negative impacts on the environment." (free translation)

[207] See, A. MURATORI, *D.M. N.264/2016: criteri realmente indicative per riconoscere I sottoprodotti?* in *Ambiente e Sviluppo* 4, 2017, pp. 251 ff.

In fact, the entrepreneur must demonstrate that the residue, which he qualifies as a by-product, complies with the requirements of Article 184-bis of the Environmental Code and the applicable regulations concerning that type of product[208] .

For example, the certainty of the reuse of the by-product could be demonstrated through contracts or sales invoices for the transfer of the by-product[209] to a user, or by documentation certifying its function in the production process for which it is intended, and by technical data sheets containing information on the characteristics of the by-product and its storage and handling methods[210] .

On this point, Ministerial Decree 264/2016 establishes general, indicative and non-binding criteria, specifying that the burden of proof on the entrepreneur – and on any entity involved in the supply chain – can be satisfied «by any means and also by methods and with reference to substances and objects other than those specified in this decree, or which meet different criteria, that a substance or object resulting from a production cycle is not waste but a by-product»[211] .

The reference to a possible distortion of the concept of by-products can be understood in two ways. Regulatory uncertainty might discourage entrepreneurs

[208] Pursuant to Article 9, paragraph I, of D.M. 264/2016, «the competent authorities carry out, through inspections, controls, and sampling, the necessary checks to verify compliance with the provisions of this decree. On this point, some of the doctrine recalls that the ministerial decree in question does not specify which authorities are competent in the matter»; see, R. LEONARDI, *op.cit.*, p. 99.

[209] Regarding this point, it is recalled that Article 10, paragraph I, of Ministerial Decree 264/2016, to facilitate the exchange of demand and supply of by-products, states that «the territorially competent Chambers of Commerce shall establish a specific register in which producers and users of by-products are registered, free of charge». Registration on this exchange platform does not constitute any obligation but encourages the expansion of a marketplace intended for the marketing of by-products.

[210] See, S. MAGLIA, P. PIPERE, L. PRATI, L. BENEDUSI, *op. cit.*, pp. 186 ff.

[211] Thus, Article 4, paragraph II, of Ministerial Decree 264/2016.

from investing in reusing by-products, as misclassifying a by-product could result in criminal liability for illegal waste management[212]. Conversely, the same regulatory uncertainty can create opportunities for dangerous and intentional evasive practices that are criminally relevant, carried out by reckless entrepreneurs or, in the most serious cases, organized crime groups[213]

Current regulatory gaps are one of the main strengths of eco-mafias. This necessitates a response from the legal system, primarily in the form of preventive measures[214]. In this context, regulating by-products provides an opportunity to explore the relationship between regulatory clarity and anti-mafia measures. Adopting certain operational solutions can promote ethical entrepreneurship and prevent mafia infiltration in a crucial circular economy sector[215]. Adopting certain

[212] Regarding that, see COMANDO DEI CARABINIERI PER LA TUTELA AMBIENTALE E TRANSIZIONE ECOLOGICA, *Il processo di transizione ecologica e i possibili fattori di rischio,* in OSSERVATORIO NAZIONALE LEGALITÀ (ed.), *Ecomafia 2022*, Edizioni Ambiente, Milan, 2022, pp. 85 ff.

[213] V. ODDI, *Ambiente e criminalità organizzata transnazionale: quale futuro per la cooperazione giudiziaria e di polizia?*, in *La Legislazione Penale,* 4, 2022, pp. 233 ff. and A. NICOLI, *Economia circolare e contrasto alla criminalità ambientale nel ciclo dei rifiuti. Un approccio integrato,* in *Federalismi,* 7, 2023, pp. 129 ff. Regarding ecomafia infiltration phenomena in the economic sector: G. MANUGUERRA, *L'influenza della criminalità organizzata sul settore ambientale: il fenomeno delle ecomafie,* in S. SPARACIA, F.A. CIMINO (ed.), *Nuovi orientamenti di economia e diritto in tema di tutela ambientale,* Ipsoa, Milan, 2019, p. 136; P. PINOTTI, *The economic costs of organised crime: evidence from southern Italy,* Discussion topics, Bank of Italy, 868, 2012.

[214] On this point, reference is made to A. DEPIETRI, N. GRANATO, M. COCCONI, *Public Administration and Agromafias: Administrative Law Profiles Between Coordination, Prevention, and Control in the Food Sector,* in *CERIDAP,*3, 2025, pp. 29 ff. DOI: 10.13130/2723-9195/2025-3-67.

[215] Although the theme of anti-mafia measures only tangentially touches upon this discussion, it seems appropriate to refer to some sources that can provide a general overview about the economic scenario where mafias act, see N. DALLA CHIESA, *L'impresa mafiosa tra capitalismo violento e controllo sociale,* Cavallotti University Press, Milan, 2022; F. SIRACUSANO, *L'impresa a partecipazione mafiosa tra repressione e prevenzione ,* in *Archivio Penale,* 3, 2021, pp. 1 ff and A.

operational solutions can help promote ethical entrepreneurship and prevent mafia infiltration in a crucial sector for the circular economy. For example, establishing white-lists or certified registers of companies authorized to handle and trade by-products could be an effective strategy.

2.4.3 Italian Regional Intermediate Bodies in By-Product Regulation: Issues of Governance and Application

Moving beyond the Italian context, it is interesting to consider the role that the regions[216] can play through a *bottom-up* approach. With reference to the requirement of normal industrial practice, for example, it is interesting to note the recent D.G.R. 10-6722/2023 of the Piedmont Region, which approved «Regional Guidelines to support the application of the by-products regime under Article 184 bis of Legislative Decree 152/2006» and, with reference to various sectors (i.e. textiles, transport, raw materials for construction, etc.), identified normal industrial practice activities, specifying that they can also be carried out in different combinations depending on the specifications of the product to be obtained.

LA SPINA, *The anti-mafia fight in Italy and abroad* in F. ALLUM, I. CLOUGH MARINARO, *R.* SCIARRONE *(*eds.), *Italian Mafias Today,* Cheltenham, Edward Elgar Publishing, 2019.

[216] In general, the theme relates to the challenges inherent in the implementation of European Union law within a multilevel system. For an overview, see G. SAPUTELLI, *Le Regioni e l'attuazione del diritto europeo nel sistema europeo multilivello,* in *Federalismi,* 20, 2022, pp. 571 ff.; A. GALLETTI, *Il ruolo delle Regioni nell'Unione europea. La partecipazione delle Regioni italiane al processo di attuazione e formazione del diritto europeo,* in *dirittiregionali.it,* 1, 2019, p. 34; P. SCARLATTI, *Le Regioni italiane nella fase discendente di adattamento al diritto europeo: metodi e strumenti comuni di recepimento, Federalismi,* 8, 2013, p. 1 ff; M. CARETTI, *Il ruolo delle Regioni nella formazione e attuazione del diritto comunitario,* in S. BARONCELLI (ed.), *Il ruolo del Governo nella formazione e applicazione del diritto dell'Unione Europea. Le peculiarità di un sistema multilivello,* Giappichelli, Torino, 2008, pp. 249 ff.

The coordinated and comprehensive creation of sector-specific guidelines, emphasizing guidance at the national level, could clearly define which treatments qualify as 'normal industrial practices' across different production sectors. Additionally, establishing a system of positive lists that can be regularly updated would allow regulations to evolve with technological progress, preventing the automatic exclusion of new recovery methods due to absent standardization.

In this regard, ISPRA[217] , ARPA[218], and university research centres could be tasked with providing technical and scientific opinions to reduce the arbitrariness of judicial interpretation. At the same time, it would be advisable to set up one-stop shops where companies could request, in advance, clarification on the legal framework for specific operations, based on a model similar to *advance rulings* in tax matters.

With Regional Law 16/2015, the Emilia-Romagna Region found it appropriate to establish permanent coordination to identify by-products. This cross-sector coordination includes, besides regional representatives, industry officials who, in accordance with current legislation, seek to identify specific by-products in production processes.

[217] ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) is the Italian Institute for Environmental Protection and Research, a public body under the supervision of the Ministry of the Environment and Energy Security. It coordinates the national environmental monitoring network, develops scientific studies, issues technical guidelines, and supports the implementation of EU environmental legislation in Italy, particularly in the areas of waste management, water, soil, and biodiversity protection.

[218] ARPA (Regional Agency for Environmental Protection) refers to the Regional Agency for Environmental Protection, operating in each Italian region. ARPAs are responsible for environmental control, monitoring, and enforcement at the local level, including inspections of industrial activities, air and water quality monitoring, and the assessment of ecological risks. They act in coordination with ISPRA within the National System for Environmental Protection (SNPA).

Furthermore, the Region of Tuscany has focused on laying down the «Guidelines for the application of the by-product regime in the textile industry» (Regional Council Decree 12/2020).

In view of these bottom-up regional experiences, it is evident that public bodies can play a significant role in the context of regulatory experimentation on by-products. However, despite the positive aspects, it should be noted that the absence of national coordination mechanisms could lead to disparities in implementation between different regional territories and uncertainty for companies operating in different contexts.

2.4.4 Second-Tier By-Products and the Legal Vacuum in Circular Regulation

Regarding certain regulatory issues that need attention, the term "second-tier by-products" arises: a phrase that has never been part of any official classification – whether EU or national – and therefore cannot be associated with any regulatory acknowledgment.

This observation stems from a practical consideration: there are materials derived from a first-cycle recovery and transformation of by-products that are no longer directly linked to the original production process but still retain characteristics that make them valuable in other industrial or manufacturing contexts.

The following case study is provided for consideration: the processing of a by-product may, in turn, result in a further residue whose chemical or technological properties make it suitable for reuse in a new production cycle. In this case, the determination of whether the residue, rather than being considered waste, can be classified as intermediate and innovative remains ambiguous[219].

[219] An illustrative example concerns *rice husk ash*, a residue generated from the combustion of rice husks, themselves classified as a by-product of rice milling. Rice husk ash contains a high

The provision of regulatory clarification in this regard would facilitate the enhancement of resource efficiency, thereby reducing the volume of materials that would otherwise be discarded. This, in turn, would result in the establishment of additional complementary industrial chains, which would benefit industrial symbiosis.

While this may be regarded as a relatively minor discrepancy, the implementation of specific regulatory frameworks that acknowledge and govern the utilisation of secondary by-products could serve to promote the advancement of recovery technologies across diverse sectors.

2.4.5 A Structural Gap in the Trade of By-Products: the Missing Intermediary

Unlike in the field of waste management, there is no legal provision at any level regarding the role of the by-product intermediary (except, in Italy, a few vague and inappropriate references in ministerial provisions)[220].

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percentage of amorphous silica, which gives it pozzolanic properties suitable for use as an additive in cement and concrete production. However, this material originates not directly from the primary production process, but from the further transformation of a by-product. This raises legal uncertainty as to whether it can be classified as a "secondary by-product" or whether it should instead fall under the category of waste. Clarifying this point would make it possible to enhance materials with genuine reuse potential, thus promoting industrial symbiosis and reducing the environmental and administrative costs associated with waste management procedures.

[220] The aforementioned Ministerial Decree 264/16 makes reference to it in the fourth paragraph of Article 5: «For the purposes of paragraph 3, the existence of contractual relationships or commitments between the producer of the residue, any intermediaries, and the users, from which information relating to the technical characteristics of the by-products, the relevant modes of use, and the conditions of transfer that must be advantageous and ensure the production of an economic or other benefit can be inferred, constitutes a piece of evidence.» and to the fourth paragraph of Article 8: «The responsibility of the producer or the transferee in relation to the management of the by-product is limited to the phases prior to its delivery to the user or an intermediary. In the case of

Even without this figure, it is reasonable to assume that it is an external business partner responsible for connecting producers and recipients of by-products. This commercial entity would play a key role in supporting the parties involved in concluding ongoing commercial agreements.

However, the lack of official recognition of this professional role leads to significant operational problems. For instance, it is unclear whether the intermediary can take possession of the by-product, collecting it from the seller and delivering it to the recipient. Even if this were permitted, there is a potential conflict with the regulatory requirement for the by-product to be used directly, without intermediate steps[221].

Furthermore, the existence of a by-product intermediary could ease the burden of proof that typically falls on those who intend to use the by-product. Although the issue of intermediaries does not appear to be widely discussed, even in case law, it should be noted that in only one case did the Supreme Court emphasize that the presence of a potential by-product intermediary, demonstrated through a contract, is not enough to meet the criteria for classifying the substance as a by-product[222].

Given the lack of clarity in the regulations from this point of view as well, case law continues to suggest a precautionary approach, requiring «precise technical documentation covering the characteristics of the production cycle, subsequent reuse and any subsequent treatments, the presence of characteristics suitable for meeting all relevant requirements concerning products and the protection of health and the environment, and the absence of overall negative impacts on human health»[223] .

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use by the producer himself, he retains responsibility for the management of the by-product during the utilisation phase.»

[221] S. MAGLIA, M. VIVIANA BALOSSI, *Sottoprodotti e circular economy. Guida alla corretta gestione dei residui di produzione,* Tuttambiente Edizioni*,* Piacenza, 2023, pp. 47 ff.

[222] Italian Criminal Court of Cassation 50628/2019.

[223] Italian Criminal Court of Cassation 38590/2017.

To strengthen circular supply chains, establishing an autonomous definition of the role of the by-product intermediary could be a significant step forward. Besides serving as a commercial link between producers and users, the intermediary might also handle contract preparation, technical documentation, and, on a residual basis, logistical management that does not involve changes to the by-product.

With the help of specialized certified digital platforms, managed by intermediaries and authorized by national or European authorities, this professional could contribute to standardizing technical data sheets, conformity certifications, and the development of digital traceability systems for flows.

At the same time, it would be appropriate to establish a national register of by-product intermediaries that would also be accessible at a European level. Registration should be subject to compliance with professional and technical standards, the holding of specific insurance policies, and the passing of periodic checks.

To incentivise companies that use certified intermediaries, tax and contractual advantages could be established, such as tax credits, preferential clauses in green public procurement and additional points in environmental certifications.

2.5 Comparative Overview of By-Product Regulation in France, Germany and Finland

Since Directive 2008/98/EC and its amendments set general criteria for by-products, it's important to note that while the Italian experience is significant, it is just one part of a broader discussion on this topic.

At the EU level[224], the management of by-products is based on different national models, which involve significant administrative and procedural differences[225] . Inevitably, these differences create considerable difficulties for the circulation of these reusable substances within the internal market.

For simplicity, it is helpful to compare three other models of by-product management with the Italian model.

France provides a clear example[226] . The Waste Directive was incorporated into national law by Ordonnance No 2010-1579 and later integrated into the Code de l'Environnement (Art. L.541-4-2). It defines a by-product as: «A substance or object resulting from a production process, where the primary aim is not the production of that substance or object, can be considered a by-product rather than waste under Article L. 541-1-1 if all these conditions are met: the subsequent use of the substance or object is certain; it can be used directly without extra processing apart from standard industrial procedures; it is produced as part of a production process;

[224] For an overview and one of the pioneering comparative analyses on the management of industrial residues, see M. PRIEUR (ed.), *Les déchets industriels et l'environnement,* Presses Universitaires de France, Paris, 1985.

[225] See, EUROPEAN COMMISSION, *Study to Assess Member States' Practices on By-Product (BP) and End-of-Waste (EoW),* Final Report prepared by Umweltbundesamt GmbH (EAA) and ARCADIS Belgium NV, Contract No. 070201/2018/793241/ENV.B.3, 30 April 2020.

[226] For a general overview of the waste management issue in France, see C. ENCKELL, Évolution du statut de déchet: une contribution à l'économie circulaire?, in *Revue Droit de l'Environnement,* 218, 2013, pp. 417 ff.

it complies with all product, environmental, and health standards for its intended use; and it will not cause overall harm to the environment or human health. Waste treatment operations do not count as a production process for this article».

As has been the case in the Italian legal system, French case law[227] has highlighted difficulties in classifying this category of substances on several occasions.

This is undoubtedly linked to the absence of a general implementing decree that establishes technical procedures for recognising by-products[228]. This means that compliance with the criteria must be assessed on a case-by-case basis, resulting in significant fragmentation in decisions between regions and departments.

As reported in 2018 by the *Institut de l'Économie Circulaire*[229] , these aspects of uncertainties hinder the development of industrial symbiosis supply chains on a national scale.

A distinctive feature of French law is that it combines the category of *sous-produi*t with that of *co-produit*, meaning a substance that is deliberately part of the production process and has an economic value separate from the main product. This category is mainly associated with industrial practice and is not governed by environmental law. The main risk of this unique category is that it may cause semantic and functional overlap between the two concepts, leading to classification uncertainties.

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[227] See, French Court of Cassation, Commercial Chamber, Decision No. 11-10770, 2012; Council of State, Decision No. 348912, 2013; and Administrative Court of Appeal of Marseille, *Decision No. 10MA01496,* 2012.

[228] This was initially provided for in Article L. 541-4-2 of the Code de l'Environnement, but was then repealed by Law No. 2015-992, Article 82-1.

[229] C. ENCKELL, L. CARRÉ, *Changing the status of waste to promote the circular economy. Summary of the reflections and proposals of the regulatory working group* (2014/2015), Ministry of Ecology, Sustainable Development and Energy, Paris, 2015.

Materials classified as co-products in industry are regarded as economic resources on their own[230]. However, if they do not meet the classification requirements outlined in the Waste Directive, they may be considered waste (déchets). If they are to be used as secondary raw materials, all the necessary authorisations and procedures specified in Art. L. 541-4-3 of the Code de l'Environnement, which regulate End of Waste, must be followed.

This systemic specificity thus strengthens the classification complexities of the sector, encouraging a tendency to favor case-by-case over systemic interpretations and generating critical interoperability issues between different legal systems. The German model[231] is equally noteworthy, as it implements Directive 2008/98/EC through the *Kreislaufwirtschaftsgesetz (KrWG*). Section 1, §4 of this law, closely adheres to the criteria established in Article 5 of the Framework Directive on *Nebenprodukte* (by-products).

The German legal system is characterised by an administrative practice that is particularly cautious about the above conditions, in full compliance with the legal principles of *Vorsorgeprinzip* (precautionary principle)[232] and *Gefahrenabwehr* (risk prevention).

In this context, it is noteworthy that the interpretation of "normal industrial practice" is quite restrictive. This approach significantly limits the operational

[230] See INSTITUT NATIONAL DE L'ÉCONOMIE CIRCULAIRE, *Économie circulaire et bioéconomie. l'industrie des coproduits animaux,* 2020, https://institut-economie-circulaire.fr/wp-content/uploads/2020/03/etude-bioeconomie_coproduits.pdf

[231] See F. ROSIGNOLI, *Waste Legislation in Germany and Italy. Two different Pathways,* in NOMOS, 3, 2016, pp. 1 ff.

[232] On the importance of the evolution of the precautionary principle in Germany and its role in the European scenario, see VON MOLTKE K. (1987), *The Vorsorgeprinzip in West German Environmental Policy,* in *Twelfth Report of the Royal Commission on Environmental Pollution,* H.M. Stationery Office, pp. 57 ff.

exploitation of the by-products category and the End-of-Waste regulation[233]. Furthermore, the absence of specific lists allowing substances to be classified in advance as by-products forces the competent authorities in each federal state to make a purely case-by-case assessment. The risk, in this case too, is that the rule will be applied unevenly across different regions, causing considerable uncertainty for economic operators.

Equally interesting are the models for the management and valorisation of by-products adopted by the Nordic countries, through cooperative approaches between authorities and industry.

In Finland[234] , the regulation of by-products is based on the Waste Act (*Jätelaki* 646/2011), amended by the Waste Amendment Act (714/2021), and is supported by significant case law references[235] . The Waste Act defines the general criteria for

[233] See, for example, Ministry for the Environment, Nature Conservation and Transport of the State of North Rhine-Westphalia, *Handlungshilfe zur behördlichen Prüfung des abfallrechtlichen Nebenproduktstatus* (Guidance for the Administrative Assessment of the Legal Status of By-Products), 30 January 2023. This guidance document, issued by the Ministry of North Rhine-Westphalia, provides practical instructions for competent authorities on how to assess whether a material can be classified as a *Nebenprodukt* (by-product) rather than as waste under § 4 of the *Kreislaufwirtschaftsgesetz* (KrWG). It interprets the statutory conditions—such as the certainty of further use, the absence of additional treatment beyond normal industrial practice, the integral nature of production, and the legality of reuse—and aims to ensure a consistent and precautionary application of the by-product criteria across regional administrative practice in Germany.

[234] For a reconstruction of the evolution of the waste management system before the reform, see J. SORVARI, *Developing environmental legislation to promote recycling of industrial by-products - An endless story?,* in *Waste Management,* 28(3), 2008, pp. 489 ff.; about the evolution of the waste management issue in Finland and its local impact, see P. PEURA, O. VOUTILAINEN, J. KANTOLA, *From garbage to product and service systems: A longitudinal Finnish case study of waste management evolution,* in *Waste Management,* 140, 2022, pp. 143 ff.

[235] See, Supreme Administrative Court of Finland (Korkein hallinto-oikeus), KHO:2021:95, 30 June 2021, ECLI:FI:KHO:2021:95, case no. 5484/1/19. The Court reviewed a

classifying a substance or object as *a sivutuote* (by-product), in accordance with the characteristics of the European Directive referred to above.

In this context, it is important to highlight the key role played by the Regional Centres for Economic Development, Transport and the Environment (Elinkeino-, liikenne- ja ympäristökeskus – ELY-keskus)[236]. Under the coordination of the Ministry of the Environment (Ympäristöministeriö), these Centres carry out surveillance, technical consultancy and control activities for the classification of materials.

The Finnish experience is distinguished by an evidence-based approach, whereby Life Cycle Assessment (LCA) is considered fundamental to the by-product management process[237]. This process is instrumental in measuring the environmental impacts associated with the reuse of resources.

This model is distinguished by a judicious balance between operational autonomy and environmental control[238]. This balance is achieved through a multi-

permit application to use ~320,000 tonnes of uncontaminated excavated soils for field improvement and held that the soils were waste (not a by-product). It was determined that the operation amounted to professional/installation-like waste treatment, predominantly disposal, so the environmental permit had to be refused. The reasoning was based on the lack of proof of genuine substitution of virgin materials and the disproportionate scale and duration of the works; permit prerequisites under the Environmental Protection Act (ss. 11, 12, 27, 39–40, 48–49) were not met.

[236] See, for example, the case of the ELY Centre of Pohjois-Savo: there have been three different cases concerning by-products. These decisions have considered yeast and mash (ISAVI/7043/2020), plastic, turpentine, pine oil, and aluminium (ISAVI/5409/2019), and gypsum and calcinate waste (ISAVI/1194/2015).

[237] A case study is presented by U.M. MROUEH, M. WAHLSTRÖM, *By-products and recycled materials in earth construction in Finland: An assessment of applicability,* in *Resources, Conservation and Recycling,* vol. 35, 1, 2002, pp. 117 ff. doi:10.1016/S0921-3449(01)00126-4

[238] Regarding a practical example, see D. D'AMATO, S. VEIJONAHO, A. TOPPINEN, *Towards Sustainability? Forest-Based Circular Bioeconomy Business Models in Finnish SMEs,* in *Forest Policy and Economics,* vol 110, 2010, 101848. https://doi.org/10.1016/j.forpol.2018.12.004

level authorisation system and substance life cycle assessments, which serve to mitigate the operator's responsibility.

However, it should be noted that there is a difficulty in disseminating data on the use of by-products, given the absence of public databases and limited access to decisions on the matter.

2.6 On the Opportunity to Create a Single European Market for By-Products. Challenges and Reflections Based on the European Union's Tools

2.6.1 The Case of By-Products and the Intertwining with the "Principle" of Mutual Recognition

The regulation of by-products therefore suffers from significant inconsistencies in its application across Member States. The aforementioned waste directives lay down general criteria, the implementation of which depends on the different sensitivities of the Member States. As a result, what is classified as a by-product in European country "X" may well be considered waste in country "Y"; immediately, therefore, possible negative implications in terms of the free movement of goods become apparent.

In this case, the minor issue of the single market for by-products is connected to the broader issue of implementing the mutual recognition principle, a fundamental aspect of European law[239]. As widely recognized, the mutual recognition principle, which was introduced in the late 1970s, is pragmatically

[239] For an in-depth analysis of this topic, reference is made to E. GIORGI, *Il principio di mutuo riconoscimento nell'ordinamento europeo (The principle of mutual recognition in European law),* Firenze University Press, 2020.

linked to a mechanism created to eliminate barriers to intra-Community trade caused by differences in legal systems among Member States.

At that time, the Court of Justice of the then European Economic Community handed down the *Cassis de Dijon* judgment[240] which held that measures having an effect equivalent to quantitative restrictions on imports of goods were prohibited. In this sense, it formulated the principle of mutual recognition as an instrument to remove obstacles to the freedoms of movement guaranteed by the Treaty establishing the then European Economic Community. Moreover, the Treaty on the Functioning of the European Union explicitly qualifies mutual recognition as a guiding principle of judicial cooperation in criminal and civil matters, in Articles 81 and 82 respectively[241] .

[240] CJEU, 20 February 1979, C-120/78, The ruling aimed to ascertain the legality of German legislation, which prohibited the importation of spirits with an alcohol content of less than 32° in Germany: in this case, the liqueur Cassis de Dijon. The justification provided by the German government was paradoxical, as it claimed to protect public health by limiting the proliferation of low-alcohol beverages, which would promote addiction to drinks with higher alcohol content, as well as ensuring fair trade. In 1979, the Court stated that any goods legally produced and sold in a Member State must, in principle, be allowed on the market of any other Member State. The only obstacles to free trade are therefore justifiable solely on the basis of imperative requirements (such as the effectiveness of fiscal controls, protection of public health, fairness of commercial transactions, and consumer protection) and for reasons of general interest. From the analysis of the Court's rulings following Cassis de Dijon, the following principles can be derived: States, in the absence of common regulation or harmonisation, remain free to regulate, within their territory, all matters concerning the marketing, consumption, labelling, and designation of products; however, such freedom must not result in measures that could hinder community trade; national regulation in this area constitutes an obstacle to community exchanges when it is not justified by imperative needs..

[241] On this topic, see A. ADINOLFI, I *principi generali nella giurisprudenza comunitaria e la loro influenza sugli ordinamenti degli Stati membri,* in *Rivista italiana di diritto pubblico comunitario,* 1994, p. 525.

Nevertheless, there is no consensus on the legal classification of mutual recognition. On one side, mutual recognition in terms of principle is considered a structural feature inherent in the internal market and functional to its implementation; on the other one, it is considered a mere legal technicality[242].

In relation to the European market for by-products, it can be posited that the principle (or, depending on the interpretation, the instrument) of mutual recognition would ensure uniform application of this category of substances. It can thus be concluded that material classified as a by-product by a national authority could also be recognised as such in other Member States. This would help overcome the current uncertainties arising from differing national interpretations and reduce transaction costs for businesses, which often face duplicate administrative and legal obstacles when transporting their by-products across borders.

However, it should be remembered that applying mutual recognition in the environmental sector may face significant resistance: the free movement of goods must be balanced with the need for Member States to protect public health and the environment. Despite these challenges, strengthening mutual recognition could serve as a driving force for European industrial symbiosis, helping to bridge the gap caused by current regulatory fragmentation.

[242] For a detailed reconstruction of the subject, reference should be made to E. GIORGI, *cited above*, 21 ff. In particular, the author emphasises that the doctrinal debate is complemented by the position of 'the Commission, which in the White Paper on the completion of the internal market qualified mutual recognition as a tool, foreseeing its use not only for purposes of negative integration but also for positive integration. In particular, the White Paper acknowledged that mutual recognition has become increasingly valued by Union legislation, progressively emerging as a means of realising the integration of the internal market alongside the concept of harmonisation' (free translation). Among scholars, see also V. HATZOPOULOS, *Le principe communautaire d'équivalence et de reconnaissance mutuelle dans la libre prestation de services,* Athens-Brussels, 1999, pp. 111 ff.; F. TORIELLO, I *principi generali del diritto comunitario,* Milan, 2000, p. 117; C. JANSSENS, *The Principle of Mutual Recognition in EU Law,* Oxford, 2013.

The certainty that a by-product classified as such in Italy would have the same status in France or Germany could promote the development of transnational supply chains and economies of scale, which are crucial for making the circular economy model competitive. Failing to develop tools or principles to harmonize interpretative differences at the EU level might lead to more definitive measures, such as implementing a European regulation that directly and uniformly governs the by-products market. While this approach could eliminate regulatory disparities, it might also introduce excessive rigidity, preventing adaptation to technological and industrial progress with sufficient flexibility. In fact, replacing the collaborative and dialogic spirit of European law with centralized actions may not adequately account for the sector-specific and regional differences within the by-products supply chain.

The strengthening of a circular single market, in which the promotion of trade in plant by-products plays a leading role, will help to reduce fragmentation and regulatory uncertainty.

As will be seen below, this aspect is particularly important in the context of food waste, which is largely linked to fruit and vegetable products and processed agri-food products, with significant effects.

Consider, for example, the situation of an Italian SME operating in the fruit and vegetable sector, which generates waste such as peelings, pulp or processing residues. With a clear and coordinated regulatory framework in place, these flows could be classified as by-products and then directed towards value chains (e.g. ingredients for food upcycling, production of biomaterials or use as bio-based inputs). Such an arrangement could help reduce waste streams and generate indirect benefits in environmental terms, contributing to the resource efficiency and emission reduction objectives pursued by European circular economy policies.

2.6.2 A Possible Trump Card to Promote a European by-product Supply Chain. Unwritten Notes on the IPCEI (Important Projects of Common European Interest) Score

As mentioned above, any obstacle to developing transnational supply chains risks discouraging investment in industrial symbiosis practices. Therefore, the investigation should effectively use existing economic and legal tools aimed at harmonizing the single market.

In this case, linking the issue of by-product valorisation with that of IPCEIs (Important Projects of Common European Interest) appears necessary[243] . These instruments are designed to promote the implementation of strategic cross-border initiatives in sectors vital for European competitiveness. Specifically, systemic projects supported by multiple Member States can receive derogations in State aid regulations, thanks to a more flexible and coordinated regulatory framework.[244]

Unlike ordinary state aid, Important Projects of Common European Interest (IPCEI) have structural features that are gradually shaping them as paradigmatic models of the new European industrial policy[245] .

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[243] Provided for in Article 107(3)(b) TFEU. Initially, they constituted a mere derogation from the general prohibition of State aid, allowing public funding for transnational industrial projects when these significantly contributed to economic growth, internal market integration, territorial cohesion, and the resilience of the European Union. The reference is to the European Commission, *Communication on the criteria for analysing the compatibility of IPCEIs with the internal market pursuant to Article 107(3)(b) of the TFEU,* 2021/C 528/02, in OJ C 528 of 30 December 2021.

[244] Regarding the strategic value of the institution in question, the reference is primarily to the "Letta" and "Draghi" reports. M. Draghi, previously analysed.

[245] See, G.P. MANZELLA, *Gli IPCEI come modello della politica industrial europea,* in *Federalismi,* 20, 2025, pp. 57 ff. About the growing centrality of this tool, see M. COCCONI, *Il ruolo degli "Important Projects of Common European Interest" nella trasformazione dell'amministrazione industriale europea e nazionale,* in *CERIDAP,* 4, 2025, pp. 1 ff.

A. BORONAT, *IPCEI: a market design tool for pro-competitive industrial policies in Europe?* in *Journal of European Competition Law & Practice,* 2024, pp. 526 ff.

Firstly, IPCEIs demand extensive transnational collaboration, bringing together multiple Member States and a network of businesses, universities, research centres, and public and private entities, all working in synergy to execute integrated projects of shared interest[246] .Moreover, IPCEIs cover the entire industrial value chain, from research and development (R&D) to the initial industrial application and commercialization of results, addressing the usual fragmentation of aid. They also promote sharing of risks and benefits with the community, as the projects they fund must produce positive effects, known as "spillovers".

To be approved by the Commission, these projects must have a positive impact at EU level, both in terms of advanced technological innovation and strategic autonomy in key sectors such as energy, microprocessors, sustainable mobility and digitalisation. In addition to the IPCEIs already approved[247], there are five

[246] They are based on strong integration between the European level and the national level, both in the upward phase – of proposal and planning – and in the downward phase – of management, implementation, and control. The direct involvement of Member States is an essential condition for activating the instrument, as each IPCEI project must be notified to the European Commission by the promoting States, which assume responsibility for selecting the beneficiary companies and ensuring the sustainability of the intervention. Although the European Commission maintains a role of strategic guidance and ex-ante control over the compatibility of state aid with the internal market (pursuant to Article 107, paragraph 3, point b) TFEU), the concrete implementation of the measures mainly falls on the individual States. It is their responsibility not only to disburse financial contributions and prepare the necessary administrative procedures but also to monitor the progress of the projects, verify compliance with declared obligations, and ensure the achievement of the declared objectives.

[247] The reference is to the cases of the IPCEI Microelectronics (the first approved in 2018 and updated in 2023) and the IPCEI Hydrogen (Hy2Tech and Hy2Use, approved in 2022). The former has mobilised public and private investments for the development of advanced technologies in semiconductors and integrated electronic systems; the latter focuses on creating a European supply chain for renewable hydrogen, aimed at promoting decarbonisation, reindustrialisation, and European leadership in the sector.

proposals[248] for new projects currently being prepared and evaluated at EU level. As far as this document is concerned, it is worth highlighting the recent proposal on advanced materials for green technologies[249] entitled «Advanced Materials for Industrial Leadership». Notably the document does not touch in any way on the issue of the potential of by-products in terms of circularity performance.

Considering that European industrial leadership should also focus on raw material self-sufficiency, it would be appropriate to call for an evolution of the IPCEI institution aimed at the multidimensional valorisation of by-products. This should promote integrated approaches that help overcome current regulatory barriers and enable the exploitation of economies of scale which are difficult to achieve at the national level alone.

Despite the well-known difficulty of reconciling the inherently horizontal and fragmented nature of the by-products sector with the vertical and sectoral logic that traditionally guides IPCEIs, addressing this challenge would help establish better coordination among Member States, attract private investment, and foster greater legal certainty and competition protection.

[248] Focusing on the sectors of advanced materials for green technologies, on services related to Artificial Intelligence, on computational infrastructure within the perspective of the digital single market, and on advanced technologies in semiconductors, with a specific focus on the needs. of the European industrial system. Finally, a new initiative dedicated to nuclear technologies has recently been announced.

[249] See European Commission, *Advancing European economic security: an introduction to five new initiatives,* COM (2024) 98 final.

2.7 Market-Based Instruments for Environmental Protection and Their Role in the Regulation of By-Products

2.7.1 Preliminary Considerations on Market-Based Instruments for Environmental Protection

Recognizing ongoing classification issues for by-products and the lack of a true single market for production residues, it is necessary to advance the discussion through a comprehensive analysis of tools available under European law and, by extension, those of individual Member States. These tools can support the ecological transition within the industry, including the use of these materials. The analysis primarily concentrates on market-based instruments for environmental protection, aiming not merely to review existing institutions but to facilitate a systemic reorganization of these institutions in the by-products sector.

Unlike the "command and control" model, market instruments do not impose rigid standards from outside, but guide economic behaviour by internalising the value of environmental protection in trade dynamics[250] . To clarify, command and control mechanism[251] is linked to a regulatory strategy based on setting

[250] See M. CAFAGNO, *Strumenti di mercato a tutela dell'ambiente,* in G. ROSSI (ed.), *Diritto dell'ambiente, cit. pp.* 192 ff.

[251] According to the OECD, *«command and control policy refers to environmental policy that relies on regulation (permission, prohibition, standard setting and enforcement) as opposed to financial incentives that are economic instruments of cost* internalisation' (*https://stats.oecd.org/glossary)»*. See also, R. CELLERINO, *Comando e controllo,* in G. GAMBA, G. MARTIGNETTI (eds..), *Dizionario dell'ambiente,* Giappichelli, Torino, 1995; F. SALVIA, *Gli strumenti giuridici della materia ambientale,* in *Rivista Giuridica dell'Ambiente,* 2, 1993, pp. 209 ff.; M. RENNA, *Il sistema degli standard ambientali tra fonti europee e competenze nazionali,* in B. POZZO, M. RENNA (eds..), *L'ambiente nel nuovo Titolo* V *della Costituzione,* Giuffré, Milan, 2004, pp. 93 ff.; M. CAFAGNO, *Principi e strumenti di tutela dell'ambiente come sistema complesso, adattivo,*

standards, obligations, and prohibitions associated with various sanctioning mechanisms with a function[252]. Environmental regulation through authoritative instruments is split into two key stages. The command phase involves individual governments setting rules that specify obligations and bans for activities that could harm the environment. The control phase includes public administrations checking that these rules are followed. Typical examples include setting general standards or establishing procedural measures.

The gradual growth of market instruments stems precisely from the awareness that corrective interventions by the public sector, typical of command and control, although necessary, encounter numerous limitations[253]. One of the most common criticisms is that these instruments offer a diversification of obligations and standards (capable of considering all the different variables and circumstances) based on overly rigid and sometimes outdated information and estimates. Another issue is that command and control measures tend to suppress private incentives and motivation to seek innovative and more environmentally friendly solutions, as individual economic operators are not encouraged to meet the environmental

comune, cit.; ID.,*Strumenti di mercato a tutela dell'ambiente ,* in G. ROSSI (ed.), *Diritto dell'ambiente,* cit., pp. 186 ff; F. FONDERICO, *Limiti e standard,* in R. FERRARA, M.A. SANDULLI (eds..), *Trattato di Diritto dell'ambiente,* Volume II, Giuffré, Milan, 2014, pp. 57 ff.

[252] S. KINGSTON, V. HEYVAERT, A. ČAVOŠKI, *European Environmental Law,* Cambridge University Press, Cambridge, 2017, pp. 120 ff. From a national perspective, see F. FRACCHIA, *I procedimenti amministrativi in materia ambientale,* in A. CROSETTI, R. FERRARA, F. FRACCHIA, N. OLIVETTI RASON, *Introduzione al diritto dell'ambiente,* Laterza Publishers, Bari, 2008, 177 ff.

[253] It often takes time to define the technical standards of admissible products, and it is then difficult for the legislator or the administration to keep pace with rapid technological changes: R.B. STEWART, *Markets Versus Environment?* in *Jean Monnet Chair Papers,* no. 19, European University Institute, Florence, 1995. See also, L. PARDI, *Gli strumenti di mercato a tutela dell'ambiente. "Nuove" forme di partecipazione, responsabile e sussidiaria dei private all'esercizio delle funzioni,* Editoriale Scientifica, Napoli, 2012, pp. 85 ff.; S. VERNILE, *L'ambiente come "opportunità". Una riflessione sul contributo alla tutela ambientale da parte del "secondo" e del "quarto" settore tra greenwashing, economia e nudge regulation,* in *Il Diritto dell'economia,* 3, 2022, pp. 11 ff.

protection levels set during the command phase, since there is no economic benefit to behaving more virtuously.

However, market-based instruments for environmental protection aim to stimulate companies and individual operators to seek innovative solutions that improve existing levels of environmental protection, as the adoption of such solutions ensures an economic advantage or, conversely, a disadvantage[254].

Furthermore, market instruments have the capacity to assume a strategic function within the domain of by-products, through the promotion of a market that aims to enhance the value of materials that would otherwise be discarded. This is in full compliance with the circular production model that is stipulated by the European Green Deal.

Excluding traditional market instruments like taxes, environmental levies, and subsidies, the issue of by-products is closely related to mechanisms that directly influence industrial management and market structures: environmental certification systems and Green Procurement. These, in various ways, can promote the valorization of production residues and foster the development of a circular economy based on industrial symbiosis.

[254] A turning point in the shift from policies solely focused on command and control instruments to others that also envisaged the use of economic instruments in an integrative manner, responding to market dynamics, was the issuance in 2007 of the Green Book on market-based instruments used for environmental policy and other related purposes. With this soft law instrument, the European Commission emphasised the need to give greater space to market-based instruments for environmental protection, with a Green Paper dedicated explicitly to the topic. The Commission took the opportunity to emphasise that market-based instruments should increasingly be used as tools of environmental policy, significantly contributing to real change by modifying incentives for businesses and consumers. The subsequent evolution of European ecological policy confirmed this approach, resulting in a greater reliance on economic and market-based instruments. Just think of the European Emissions Trading System (ETS), established by Directive 2003/87/EC and progressively strengthened until it became the main pillar of the Union's decarbonisation policies (the reference to the latest amendment is Directive 2018/410/EU).

2.7.2 Green Public Procurement and By-Products Towards More Sustainable Patterns of Public Demand

a) Systemic Considerations

The term 'green procurement'[255] refers to a set of legal instruments aimed at integrating environmental requirements into public procurement legislation, including them in all stages of the procurement process. In this scenario, public procurement is linked to a complex cycle of expenditure aimed at interconnected, holistic, and strategic outcomes. These are economic, social and environmental needs, undoubtedly linked to the realisation of the original and all-encompassing goal of Agenda 2030: «leaving no one behind»[256].

To better understand its current scope, it is necessary to redesign its main evolutionary junctures, with a view to a multi-level perspective. Since the early 1990s, at the European level, the possibility of introducing environmental clauses in relation to the award of public contracts has been evaluated and discussed[257]. This perspective led to a new vision of public procurement, which until then had been linked to purely economic objectives to be achieved through transparent award

[255] Please, let me refer to A. DEPIETRI, *Il Green Public Procurement tra riforme, mercato e effettività,* in *Munus,* 3, 2023, pp. 787 ff.

[256] T. STOFFEL, C. CARVERO, A. LA CHIMIA, G. QUINOT, *Multidimensionality of Sustainable Public Procurement (SPP) - Exploring concepts and effects in Sub-Saharan Africa and Europe,* in *Sustainability,* 11, 2019, 6352 ff.

[257] See, M. COZZIO, *Appalti pubblici e sostenibilità: Gli orientamenti dell'Unione Europea e il modello italiano,* in *Il Giornale di Diritto Amministrativo,* 6, 2021, pp. 721 ff.; for a complete reconstruction of the various steps that marked the genesis and evolution of green procurement, see A. PERINI, *Appalti Verdi: una strategia per lo sviluppo sostenibile,* in *Le Regioni,* 1-2, 2022, pp. 147 ff.

procedures and in accordance with the principle of equal conditions between competitors[258] . The original directives on public procurement , in fact, made no mention whatsoever of environmental issues[259].

About equal conditions among competitors, there were fears that green clauses could have a negative impact, penalising all economic operators unable to bear the additional costs associated with *greener* goods and services[260] . In response to this climate of uncertainty, the Maastricht Treaty of 1992[261] and the Amsterdam Treaty of 1997[262] were introduced. While the former encouraged balanced and sustainable economic growth, the latter, by introducing the principle of integration, prompted European institutions to incorporate environmental interests into their policy scope[263] .

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[258] For a critical perspective on the primacy of the principle of free competition, the reference is to M. CLARICH, *Considerazioni sui rapport tra appalti pubblici e concorrenza nel diritto europeo e nazionale,* in *Diritto Amministrativo,* 1-2, 2016, pp. 72 ff. In particular, the author emphasises that: «In reality, the legal basis of the European directives on public procurement has always been founded, not on the principles of the Treaties concerning competition, but rather on the principles of free movement of goods, freedom of establishment, and free movement of services explicitly referenced in the preambles and recitals of the new directives».

[259] The reference is to Directives 1992/50/EEC on the award of public service contracts, 1993/36/EEC on the award of public supply contracts, and 1993/37/EEC on the award of public works contracts.

[260] See G. FIDONE, F. MATALUNI, *Gli appalti Verdi nel Codice dei Contratti Pubblici,* in *RQDA,* 3, 2016, p. 8.

[261] Then came into force on 1 January 1993.

[262] Entered into force on 1 May 1999.

[263] This principle, originally enshrined in Article 6 of the EC Treaty, is now set out in Article 11 of the TFEU, which states: 'The requirements linked to environmental protection must be integrated into the definition and implementation of the Union's policies and actions, in particular with a view to promoting sustainable development'. Among scholars, see L. KRAMER, *Manuale di diritto comunitario per l'ambiente,* Giuffrè, Milan, 2002, pp. 90 ff., G. GARZIA, *Bandi di gara per appalti pubblici e ammissibilità delle clausole c.d. 'ecologiche',* in *Foro amministrativo CdS,* 2003, 3515 ff., F. DE LEONARDIS, *La disciplina dell'ambiente tra Unione Europea e WTO,* in *Diritto*

Amministrativo, 2004, pp. 513 ff., R. FERRARA, *Modelli e tecniche della tutela dell'ambiente: il valore dei principi e la forza della prassi*, in *Foro Amministrativo* TAR, 6, 2009, 1945, ID. *La tutela dell'ambiente e il principio di integrazione: tra mito e realtà,* in *Rivista Giuridica dell'Urbanistica,* 1, 2021, pp. 12 ff., C. FELIZIANI, *Industria e ambiente. Il principio di integrazione dalla Rivoluzione Industriale all'economia circolare,* in *Diritto Amministrativo,* 4, 2020, pp. 843 ff.

The extensive and widespread work of the Commission[264] and the Court of Justice of the European Union[265] led the European legislator to increase the promotion and

[264] To take a first concrete step towards an integrative synthesis between ecological considerations and the regulation of public procurement, between the late 1990s and the early 2000s, the European Commission adopted the Green Paper 106, the White Paper 106, and several communications on the topic; see Communication from the Commission, 27 November 1996, COM (1996) 583 final., *Green Paper. Public procurement in the European Union. Points for reflection for the future*. As far as relevant here, reference is made to what is reported on p. 47, «In this specific field, Member States (and their bodies) are paying increasing attention to environmental considerations in the context of public procurement. Due to their size, such procurements can have very significant repercussions on certain economic activities, as well as being decisive for the commercial development of some products». Communication from the Commission, 11 March 1998, *Public procurement in the European* Union, COM (1998) 143 final. In particular, for this discussion, the White Paper defines environmental protection as «a fundamental component of the modern economy», reaffirming the need to harmonise the regulation of public procurement with ecological requirements. As reported in G. FIDONE, F. MATALUNI, *op. cit*., pp. 10 ff., «The White Paper also emphasises that limits must be defined within which contracting authorities can weigh environmental and social aspects in award procedures, in compliance with Community law and the principles of transparency and non-discrimination. Based on this, the areas are indicated where the existing Public Procurement Directives allow the integration of environmental aspects into public administration purchases, i.e., in the choice of products or services compatible with environmental concerns; in the possibility of excluding candidates found guilty of violations of national environmental legislation; in the development of technical specifications that also reflect ecological values; in the integration of environmental protection into the selection criteria related to the technical capabilities of candidates; and in the possibility of including environmental aspects in the definition of the most economically advantageous tender, when referencing these elements provides a financial advantage relevant to the service subject to the contract that benefits the contracting authority directly.» These documents, in various aspects, outline the attention that the then European institutions had begun to pay to the intersection between environmental issues and the market. References include, among others, the European Commission's Communication, 24 January 2001, *Environment 2010: our future, our choice – sixth environmental action programme*, COM (2001), 31; the Communication, 15 May 2001, *Sustainable development in Europe for a better world: the European Union's strategy for sustainable development* COM (2001) 264 final; the Communication,

28 November 2001, *Interpretative Communication from the Commission on Community law of public procurement and the possibilities of integrating environmental considerations into public procurement*, COM (2001) 274 final; the Communication, 18 June 2003, *Integrated product policy. Developing the concept of "environmental life cycle,"* COM (2003), 302, final. Notably, the Communication of 16 July 2008, titled *Public procurement for a better environment*, COM (2008) 400 final, is worth mentioning. Starting with the economic data related to public expenditure, the document illustrates the potential benefits of green purchasing, which could bring significant advantages to the entire European economy. Furthermore, it encourages public authorities to consider the life cycle of products and services and to promote the use of materials recovered from waste, thereby positively impacting waste reduction.

[265] CJEU, 17 September 2002, C-513/99, *Concordia Bus Finland Oy Ab v Helsingin kaupunki and HKL Bussiliikenne.* The same originated from a service procurement procedure initiated by the city of Helsinki to award a management contract for a city bus line. Among the various awarding criteria listed in the tender notice to determine the most advantageous offer, a reward-based criterion was reserved for all offers that included reduced noise and nitrogen oxide emissions. For a detailed analysis of the judgment in question, refer to M. LOTTINI, *Appalti comunitari: sulla ammissibilità di criteri di aggiudicazione non prettamente economici*, in *Foro amministrativo* CdS, 9, 2002, pp. 1936 ff., M. BROCCA, *Criteri ecologici nell'aggiudicazione degli appalti*, in *Urbanistica e appalti*, 2, 2003, 168 ff., D.U. GALLETTA, *Vizi procedurali e vizi sostanziali al vaglio della Corte di Giustizia*, in Rivista *Italiana di Diritto Pubblico Comunitario*, 2004, 317 ff., S. ARROWSMITH, *The Law of Public Utilities and procurement: Regulation in the EU and UK*, I, London, 2014, pp. 739 ff; G. LEONE, *Appalti pubblici e tutele sociali: la promozione dell'occupazione dei soggetti svantaggiati,* in D. GAROFOLO, *Appalti e lavoro. Volume primo. Disciplina pubblicistica*, Giappichelli, Milan, 2017, pp. 11 ff. See also, CJEU, 4 December, 2003, C-448/01, *EVN A.G., Wienstrom Gmbh C. Republik Osterreich.* The text of the judgment is reported in *Urbanitica e Appalti*, 12, 2004, with a comment by B. POGACE, *I criteri ambientali negli appalti pubblici: dalle prime pronunce della Corte di Giustizia alla nuova direttiva 2004/18*. With regard to the dispute and its legal implications, see also M. PETRACHI, *La tutela dell'ambiente nel prisma della transizione ecologica,* Giappichelli, Milan, 2023, pp. 64 ff.

dissemination of sustainable public procurement with a new package of Directives in 2004[266], later replaced by the current regulations of 2014[267] . Specifically, these are Directives 2014/24/EU, concerning procurement in ordinary sectors, 2014/25/EU, on procurement procedures by entities operating in the water, energy, transport and postal services sectors, and 2014/23/EU, on concession contracts. In light of these measures, the configuration of public procurement for sustainability is clear. Recital 2 of Directive 2014/24/EU states that public procurement is a key pillar of the Europe 2020 Strategy, as it is one of the market-based instruments necessary to achieve innovative, sustainable and inclusive growth, while ensuring the most efficient use of public funds.

Under the principle of integration, environmental concerns are incorporated at every stage of public procurement. This begins with technical specifications, which now allow contracting authorities to specify particular ecolabels. It also extends to the contract execution phase, where authorities can require the use of specific environmental management systems or generally enforce various ecologically sustainable conditions[268] .

About the contract award phase, the package of directives intervened with reference to the concept of the most economically advantageous tender, which began to be assessed in two different ways that the contracting authority is required

[266] The jurisprudential principles defined by the Court of Justice have been adopted by the European legislator with Directives 17/2004/EC and 18/2004/EC, which recognised the authority of contracting authorities to consider environmental factors during the awarding and execution of contracts. This marked a significant initial milestone, but it is undoubtedly still far from a systematic application of environmental criteria within public procurement.

[267] C. VIVIANI, *Appalti sostenibili, Green Public Procurement e Socially Responsible Procurement,* in *Urbanistica e Appalti,* 8-9, 2016, pp. 995 ff.

[268] *Funditus,* see O. HAGI KASSIM, *I criteri di sostenibilità energetica e ambientale negli appalti pubblici. L'emersione dell'istituto degli appalti verdi nel panorma europeo e nazionale,* in *Italiappalti.it,* 14 February 2017.

to select *ex ante*: the traditional quality/price ratio or the new cost/effectiveness comparison criterion[269].

The definition of the quality/price ratio permits the inclusion of environmental and social quality criteria in the contract. However, applying the cost/effectiveness comparison criterion is more complex, as it is closely connected to the concept of product life cycle cost. Directive 2014/24/EU provides a definition rooted in the understanding of life cycle[270].

The life cycle is defined as the set of «consecutive and/or interconnected stages, including research and development to be carried out, production, trade and related conditions, transport, use and maintenance, of the life of the product or work or service provision, from the acquisition of raw materials or the generation of resources to disposal, dismantling and end of service or use»[271] .

The life-cycle cost, therefore, «includes all costs arising during the life cycle of works, supplies or services». The concept covers internal costs, such as research to be carried out, development, production, transport, use and maintenance, and final disposal costs. Still it may also cover costs attributable to environmental externalities[272]. In other words, the environmental implications of the tender are assessed in terms of costs and economic savings[273]. Obviously, the measurement of

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[269] On this point, see C. VIVIANI, *Green Public Procurement e Socially Responsible Procurement, cit.* pp. 995 ff. The reference is to Article 67 of Directive 2014/24/EU.

[270] See, in particular, Article 67 of Directive 2014/24/EU, which includes among the various criteria the quality and technical excellence, aesthetic and functional characteristics, accessibility for disabled persons, the reduction of energy consumption of the work and the product, its maintenance costs, etc.

[271] Thus, Article 2, paragraph 1, point 20 of Directive 2014/24/EU.

[272] In these terms, see recital 96 and Article 67 of Directive 2014/24/EU. Among scholars, see C. VIVIANI, *Green Public Procurement e Socially Responsible Procurement*, *cit.* pp. 996 ff.; O. HAGI KASSIM, *I criteri di sostenibilità energetica e ambientale negli appalti pubblici. L'emersione dell'istituto degli appalti verdi nel panorma europeo e nazionale. cit.*

[273] C. VIVIANI, *Green Public Procurement e Socially Responsible Procurement, cit*.

the cost of life must be based on non-discriminatory and objective criteria and on data that economic operators can provide with ordinary diligence; it is the responsibility of the contracting authority to specify *in advance* the method it will use[274] .

Although these directives were an extremely important step towards the advent of a Green Revolution in Europe, some legal scholars have pointed out that the application of the environmental requirements contained therein remains purely optional and complex to implement[275] .

In any case, with particular reference to some of the Green Deal's implementing measures, it is worth briefly mentioning the recent emergence, also within the EU's regulatory framework for the sector, of a so-called *mandatory* approach, characterised by the introduction of provisions aimed at regulating in mandatory terms what to buy[276] .

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[274] Art. 68 Directive 2014/24/EU.

[275] O. HAGI KASSIM, *I criteri di sostenibilità energetica e ambientale negli appalti pubblici. L'emersione dell'istituto degli appalti verdi nel panorma europeo e nazionale, cit.* Furthermore, see recital 95 of Directive No. 24/2014, where it was not deemed necessary to 'establish general mandatory requirements for contracts in the environmental, social, and innovation sectors' due to 'the significant differences between individual sectors and markets.'

[276] Reference is made to R. CARANTA, *Towards mandatory SPP for buildings/works,* in *European Journal of Public Procurement Markets,* 4, 2022, pp. 9 ff.; W. JANSSEN, R. CARANTA (eds..), *Mandatory Sustainability Requirements in EU Public Procurement Law. Reflections on a Paradigm Shift,* Oxford, Bloomsbury, 2023. The reference, for example, is to the sectors of road transport, office equipment, and energy performance in buildings. In this regard, see also A. MALTONI, *Contratti pubblici e sostenibilità ambientale: da un approccio "mandatory-rigido" ad uno di tipo "funzionale?*, in *CERIDAP,* 3, 2023, pp. 64 ff. In note 70, in fact, the author emphasises how, for example, 'Article 70 of the EU Proposal for a Regulation on Batteries and Waste Batteries, which repeals Directive 2006/66/EC and amends Regulation (EU) 2019/1020, establishes that contracting authorities and contracting entities, on the one hand, must take into account, in public procurement for batteries or products containing batteries, the environmental impact during their lifecycle, to ensure that this impact is minimised; on the other hand, they are encouraged to include

In this context, it's useful to briefly mention Italian public procurement regulations, which, despite various updates[277], have consistently emphasized the importance of specifying technical requirements for certain product categories to qualify as green. This includes references to CAM, or minimum environmental criteria. Within this framework, the contracting public administration provides for or applies bonus criteria for bids that meet environmental requirements higher than

technical specifications and award criteria to ensure that the choice falls on a product among those with a significantly lower environmental impact throughout its lifecycle. Furthermore, it is envisaged that the Commission may establish, through delegated acts, mandatory minimum criteria for green public procurement. As reiterated by the Author, concerning the future possibilities that the Union's regulatory framework for green procurement may adopt further mandatory characteristics, there are differing doctrinal positions. Pertaining to the fact that GPP should only be binding in specific sectors with a greater environmental impact, see K.-M. HALONEN, *Is public procurement fit for reaching sustainability goals? A law and economics approach to green public procurement,* in *Maastricht Journal of European and Comparative Law,* 2021, vol. 28(4), pp. 553 ff. Regarding the fact that GPP must gradually shift to a fully mandatory approach, see, for example, L. MÉLON, *More Than a Nudge? Arguments and Tools for Mandating Green Public Procurement in the EU,* in *Sustainability,* 12, 2020, pp. 15 ff.

[277] The evolution of public procurement legislation in Italy begins with the Royal Decrees of 1923-1924, passes through the Merloni Law of 1994, the 2006 Code (D.Lgs. 163/2006), the 2016 Code (D.Lgs. 50/2016) and arrives at the new Code (D.Lgs. 36/2023, amended by D.Lgs. 209/2024), which aims at simplification, digitalisation, and greater transparency. As pointed out by the Italian Council of State, the evolution of the procurement system can be summarised in three phases: a "unipolar" phase, characterised by purely accounting objectives focused on the lowest price; a "bipolar" phase, in which, alongside the accounting aspect, the need to protect competition and the market has emerged; and finally, a "multipolar" phase, in which public contracting must also consider environmental and social variables. See, Italian Council of State, Judgment 4701/2024; See the relevant note on the judgment by C. TOZZI MARTELLI, *Consiglio di Stato, Sez. III, 27 May 2024, no. 4701,* in *CERIDAP,* 2, 2024, pp. 390 ff.

the minimum[278] and emphasises that failure to include the CAM in the tender documentation renders the tender and the entire procedure unlawful[279] .

Their provision establishes several environmental objectives, including pollution reduction and climate change mitigation. Notably, it emphasizes promoting circular economy models by enhancing material efficiency and adopting a Life Cycle Thinking approach dedicated to eco-design.

b) By-Products and Green Public Procurement in a Systemic Perspective

In the pursuit of attaining optimal circularity standards, it is imperative to deliberate on the prospective implications of specific technical specifications stipulated within tenders, with a view to assessing their potential to augment the value of by-products.

From a bottom-up perspective, it is noteworthy that the mandatory approach of minimum environmental criteria adopted in Italy could serve as a source of inspiration for European institutions and the individual legal systems to strengthen the regulation of public demand.

By establishing mandatory minimum environmental criteria, clauses could be formulated to encourage the utilisation of by-products, to catalyze market transformation towards economies of scale, and guide businesses towards more sustainable and efficient production models.

This necessitates the enhancement of legal certainty concerning the classification of by-products (in order to minimise interpretative ambiguities for businesses and contracting authorities as much as possible) and the development of

[278] Italian Council of State, Judgment 9879/2022

[279] Italian Council of State, Judgment 2799/2023. Inevitably, a contract entered into in violation of the standards requiring the CAM must be considered cancellable (or even null), with consequent liabilities for the managers who concluded it.

technical and digital tools that ensure transparency and reliability throughout the entire supply chain. It is important to acknowledge that these aspects constitute a component of a future perspective, yet are not currently in effect.

Notwithstanding, the public procurement system can still be regarded as an efficacious instrument for promoting the reuse of by-products, even in the absence of specific mandatory criteria. In this sense, the award criteria (non-mandatory ones) set out in tender notices are currently the most effective method of encouraging competition between economic operators in terms of quality.

As will be demonstrated in the specific case of by-products in the agri-food sector, these aspects highlight the proactive and co-creative role that public administrations can play in orienting public demand towards circularity solutions. The inclusion of award criteria linked to the use of by-products can, in fact, serve as an industrial policy tool, capable of encouraging competition between economic operators not only on price, but also on environmental and social quality. In this way, public administrations actively participate in the construction of circular supply chains, promote industrial symbiosis processes, and support a more efficient use of resources.

There are many practical applications. In the construction sector, for instance, proposals that involve the utilisation of industrial by-products to substitute for natural aggregates in cement or asphalt mixtures may be eligible for consideration. In the field of street furniture, proposals that incorporate materials derived from agricultural by-products (e.g. rice straw, olive pomace, vegetable fibres) in the fabrication of diverse components may be meritorious. In addition, within the textile industry, proposals for the utilisation of yarns derived from agri-food by-products (e.g. citrus waste, coffee grounds) could be financially incentivised. The inclusion of such clauses does not have a discriminatory effect, as it does not impose mandatory requirements but incentivizes the most innovative companies through a scoring mechanism.

At the same time, it helps generate economies of scale, stimulates demand for by-products, and promotes the spread of industrial symbiosis practices.

2.7.3 The Role of Certification in the Legal Qualification and Market Valorisation of By-Products

a) A Brief Overview

The concept of environmental certification[280] is widely used to encompass a range of different instruments aimed at pursuing environmental protection objectives. Specifically, it refers to forms of certification aimed at creating confidence in the markets regarding the compliance of certain products, production processes or producers' organisational systems with specific, generally non-binding environmental protection standards.

The logic behind these tools is the result of intensive planning at European level[281] . In fact, certifications aim to bridge the information gap between producers

[280] A. BENEDETTI, *Le certificazioni ambientali,* in G. ROSSI (ed.), *Diritto dell'ambiente,* cit., 207 ff. and *amplius* ID., *Certezza pubblica e certezze private. Poteri pubblici e certificazioni di mercato,* Milan, 2010. See also F. FRACCHIA, M. OCCHIENA (eds..), *I sistemi di certificazione tra qualità e certezza*, Egea, Milan, 2006, pp. 23 ff.; M. DE ROSA, *Le certificazioni ambientali e la responsabilità sociale del territorio*, in *IANUS*, 2, 2012, pp. 2 ff.; S. VERNILE, *L'ambiente come "opportunità". Una riflessione sul contributo alla tutela ambientale da parte del "secondo" e del "quarto settore" tra greenwashing, economia circolare e nudge regulation,* in *Il Diritto dell'Economia*, 3, 2022, pp. 11 ff. e R. LEONARDI*, I principi europei a tutela dell'ambiente e gli strumenti di mercato*, in *Rivista Giuridica Europea*, 2, 2022, pp. 1 ff. J.M. PONTIER. *La certification, outil de la modernité normative*, in *Recueil Dalloz*, 1996, 41, pp. 355 ff.

[281] The Sixth Community Action Programme on the Environment, entitled "Environment 2010: Our Future, Our Choice" and valid for the period 2002-2012, promoted the development of environmental certifications, emphasising the need to go beyond a purely legislative approach to adopt a strategic perspective capable of guiding the decisions of economic operators, consumers,

and consumers, helping the latter make the most environmentally sustainable choices made by economic actors.

Certification confirms that products, production processes, organizational systems, or facilities meet specific standards through a process that may lead to issuing certificates, attaching labels, or validating documents.

Regarding product certification, European legislation regulates, for example, the so-called Ecolabel[282] , e.g. the environmental quality mark issued

policymakers, and citizens. Within this framework, among the axes of strategic action related to market collaboration, there is an explicit need to encourage the wider adoption of the Community Eco-management and Audit Scheme (EMAS) and to promote the use and assessment of the Ecolabel eco-mark's effectiveness. Subsequently, the Seventh Community Action Programme on the Environment, entitled 'Living Well Within the Limits of Our Planet' and adopted for the period 2013-2020, set nine priority objectives. Among these, the second envisaged transforming the European Union into a low-carbon, resource-efficient, green, and competitive economy. Recitals Nos. 34 and 35 of the programme highlighted that environmental and quality certification tools, particularly EMAS and Ecolabel, could significantly contribute to achieving this goal, recommending their dissemination and promotion by Member States. In line with these orientations, the Eighth Environment Action Programme for the period 2021-2030, adopted by Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022, places the realisation of the green and digital transition and the goal of climate neutrality by 2050 at its centre, in line with the European Green Deal. Among the strategic priorities is the promotion of a circular, climate-neutral, and resilient economy, in which voluntary environmental management and certification tools, such as EMAS and Ecolabel, are recognised as essential instruments to strengthen corporate responsibility, improve environmental performance, and increase consumer trust. The eighth programme also emphasises the need for greater commitment from Member States in promoting these tools through support measures, incentives, and integration into public policies, reaffirming their now structural role in European sustainability strategies.

[282] A. BARONE, *L'Ecolabel,* in F. FRACCHIA, M. OCCHIENA (eds.)*, I sistemi di certificazione, cit.*, pp. 213 ff.; see also L. BOY, *L'tco-label communautaire, un exemple de droit postmoderne. Revue internationale de droit conomique* (*R.I.D.E.),* 69, 1998, pp. 70 ff.; S. LAVALLÉE, S. PLOUFFE, *The ecolabel and sustainable development*, in *The International Journal* of *Life Cycle Assessment,* 9, 2004,https://doi.org/10.1007/BF02979076

following an analysis of the environmental impact of the product, taking into account its entire life cycle, from the raw materials used to its disposal as waste[283] .

Undoubtedly, this life cycle approach aims to promote circularity by encouraging manufacturers to consider all impacts created, even when the product or parts of it are under the direct management of other parties. This means, for example, that a company should not be satisfied with just ensuring proper disposal of its products at the end of their life but should also promote their recovery or reuse.

[283] The regulatory and technical framework relating to environmental labelling and declaration tools for products is structured across various levels, ranging from the binding regulations of the European Union to voluntary international standards. The European Union Eco-label (Ecolabel EU) is governed by Regulation 2010/66/EU (Official Journal L 27 of 30 January 2010). Distinct from the Eco-label is the system of Energy Labels, which has a legal basis in European Union law: initially in Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010, concerning the indication, through uniform labelling and information, of energy and resource consumption of energy-related products, which was later repealed and replaced by Regulation 2017/1369/EU of the European Parliament and of the Council of 4 July 2017, establishing the current framework for energy labelling. This regulation is complemented by a series of delegated acts specific to individual product categories (such as refrigerators, washing machines, televisions, lamps), which set out technical and graphical requirements for the labels. Environmental Product Declarations (EPDs) are not based on a binding European legislative act but are founded on international standards developed by the International Organisation for Standardisation (ISO), particularly ISO 14025:2006 relating to Type III environmental declarations and ISO 14040:2006 and ISO 14044:2006 concerning Life Cycle Assessment. The most widely used international scheme for applying EPDs is the International EPD® System, managed by the International EPD Council (IEC). Regarding certifications focused on the 'carbon footprint' of products, the primary reference is the technical specification developed by the British Standards Institution (BSI) with PAS 2050:2011 – Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, which was subsequently complemented by ISO 14067:2018 – Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification, which today constitutes the global standard.

The life cycle approach influences the ways certification schemes operate. Sometimes, a company must perform an LCA to accurately determine the environmental indicators used for market communication. In other cases, the life cycle analysis is not done by the company seeking the label but is conducted once by an independent body that categorizes impacts by product type and sets thresholds related to environmental parameters. The company must then gather data and indicators according to these thresholds and demonstrate full compliance to gain certification.

Production systems, on the other hand, undergo environmental audit procedures, which conclude with a certificate of compliance confirming that the production process meets a series of requirements that guarantee its sustainability (e.g. EMAS)[284] .

In this context, environmental certifications are trustworthy and verifiable tools that promote sustainability, providing assurances to both the market and consumers about actual compliance with specific ecological standards. Therefore, it is essential to distinguish them from merely declarative or instrumental practices that lack a solid technical-scientific foundation and fall into the phenomenon known as greenwashing.

b) Distinguishing Genuine Circular Valorisation of By-Products from Greenwashing Practices

As highlighted, the certification market is linked to reputational aspects that companies can boast in the context of the blue economy, to influence consumers to direct their choices towards sustainable products[285] . At the same time, on the legal

[284] *Funditus*, A. GIUSTI, *Le certificazioni ambientali: EMAS*, in F. FRACCHIA, M. OCCHIENA (eds..)*, I sistemi di certificazione*, *cit*., pp. 225 ff.;

[285] Regarding the role of the consumer within the evolution of European Union law, the development of the consumer's role in the socio-economic and market dynamics of recent decades

side, the issue of sustainability communication is intertwined with *greenwashing* and the related tools introduced by European institutions to tackle it[286] .

Greenwashing is a possibly misleading commercial tactic used to give a false impression of a product's environmental impact or benefits. Clearly, the widespread use of such practices demonstrates how deeply the business world has adopted environmental sustainability as a key aspect of market competitiveness.

With a view to meeting citizens' expectations in terms of consumption, sustainable packaging and production, as well as sustainable growth and

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has been extensively studied. Please refer to V. RUBINO, *Il ruolo del consumatore nella strategia verde dell'Unione europea: considerazioni sulle proposte normative in materia di informaizioni ambientali,* in *Eurojus,* 4, 2023, pp. 210 ff; S. LANG, G. MINNUCCI, M. MUELLER, M. SCHLAILE, *The Role of Consumers in Business Model Innovations for a Sustainable Circular Bioeconomy,* in *Sustainability,* 2023, pp. 9573 ff.; B. MIHAJLOVIĆ, *The Role of Consumers in the Achievement of Corporate Sustainability through the Reduction of Unfair Commercial Practices, in Sustainability,* 2020, p. 1009 ff.; E. MAITRE-EKERN, C. DALHAMMAR, Towards a hierarchy of consumption behaviour in the circular economy. *Maastricht Journal of European and Comparative Law*, *26*(3), 2019, pp. 394 ff. https://doi.org/10.1177/1023263X19840943; A. CLAUDELIN, V. UUSITALO, S. PEKKOLA, M. LEINO, S. KONSTI-LAAKSO, *The Role of Consumers in the Transition toward Low-Carbon Living,* in *Sustainability,* 2017, p. 958 ff.; D. LECZYKIEWICZ, S. WEATERHILL (eds..), *The Images of the Consumer in EU Law,* Oxford, 2016.

[286] Reference is made to S. CARMIGNANI, *L'informazione ai tempi della sostenibilità*, in *Rivista di Diritto Alimentare*, 1, 2024, pp. 27 ff.; F. MAFFEZZONI, *I "nuovi" limiti ed orientamenti dell'iniziativa economica privata,* in *Federalismi,* 5, 2023, pp. 53 ff.; C. COSENTINO, "*Environmental claims": quando la disinformazione «si veste di verde»* in Comparazione e diritto civile, 1, 2023, pp. 79 ss.; G. SPOTO, "*Greenwashing": tutela dei consumatori e responsabilità delle imprese*, *in Diritto agroalimentare*, 2, 2023, pp. 337 ff.; A. QUARANTA, *La retorica green e le comunicazioni ingannevoli: il greenwashing per la prima volta al vaglio del giudice di merito*, in *AmbienteSviluppo*, 6, 2022, pp. 403 ss., T. PERILLO, *Dal consumatore "debole" al consumatore "attivo": itinerari della "conversione ecologica"* in *ambientediritto.it*, 4, 2022, pp. 391 ff.; F. BERTELLI, *I green claims tra diritti del consumatore e tutela della concorrenza*, in *Contratto e impresa*, 1, 2021, 1, pp. 286 ff.

innovation, Directive 2024/825/EU[287] (which came into force last May and must be transposed by EU Member States by 2026) focuses on empowering consumers for the green transition by improving protection against unfair practices and information.

The directive in question is linked to the «Circular Economy Action Plan», focusing specifically on the policy area related to fighting green claims. Regarding this issue, there is clear data that obstructs the adoption of eco-friendly consumption practices. It should be noted that approximately 53% of green claims are vague, misleading, or unsupported, 40% lack valid evidence, and there are significant differences in transparency among 230 sustainability labels and 100 green energy labels across the EU[288].

As stated in the first recital, the directive aims to contribute to the proper functioning of the internal market, based on a high level of consumer and environmental protection, and to advance the green transition; in this regard, it is therefore essential that consumers can make informed purchasing decisions and thus promote more sustainable consumption patterns. This means that economic operators have a responsibility to provide clear, relevant, and reliable information.

In summary, the directive establishes clear criteria for how companies should substantiate their environmental claims and labels, specifies requirements for verification by independent and authorized verifiers, and introduces new rules for the governance of environmental labelling schemes to ensure they are robust, transparent, and reliable.

Generic environmental claims, such as “energy efficient”, should be reformulated based on recognised excellence in environmental performance in

[287] Directive 2024/825/EU amends Directives 2005/29/EC and 2011/83/EU on consumer empowerment for the green transition by improving protection against unfair practices.

[288] Basically, see the data produced on the EU Commission's website.

accordance with Regulation 2017/1369/EU, which contains measurable, specific and, verifiable requirements for measuring energy performance efficiency[289] .

Since, therefore, the measurability and concrete verifiability of the environmental performance of products represent the new reference framework for communicating with consumers, terms such as "conscious", "sustainable", or "responsible" will have to be removed from marketing strategies, as they are linked, among other things, to subjective factors that cannot be measured[290] .

Another key element of the considered directive is to encourage producers and consumers to focus more on product durability, especially by creating a new unified label to emphasize products with longer warranties and by banning false claims about durability. It also aims to promote replacing consumer goods only when necessary[291] .

In the context of initiatives to valorise food waste and by-products, the risk of greenwashing practices deserves particular attention. These risks arise, in particular, when projects presented as "circular" are limited to marginal recovery or recycling operations, without having a substantial impact on waste prevention, overall impact reduction or the transformation of production models.

Managing these risks requires strengthening the role of law by introducing clear legal criteria for qualifying recovery activities, transparency obligations along value chains, tools for tracking by-product flows, and mechanisms for monitoring and verifying environmental claims. In this perspective, the law can play an essential role in distinguishing between truly transformative recovery practices and purely reputational initiatives, helping to ensure that the recovery of food waste produces real and verifiable environmental benefits.

[289] See recital 10 of the directive.

[290] *Ibid.*

[291] In this regard, see recitals 19 et seq. of the directive.

c) Promoting the Valorisation of By-Products through Environmental Certification

The role of environmental certification is also especially important when considering its influence on the by-product market. Certifying that processes and products made from the valorization of by-products meet high environmental standards is a crucial step toward building trust in circular economy practices. This can be done by including specific criteria related to the traceability of material flows, the amount of recycled or recovered material, and the reduction of overall emissions from reusing processing residues.

An illustrative example is the EU Ecolabel criteria for certain construction products related to roofing materials[292] , which take into account the ratio of raw materials used to by-products, thus enhancing a company's ability to use waste and residues from industrial processes efficiently. In the paper[293] and textile[294] sectors, on the other hand, the criteria are limited to including minimum percentages of recycled material, thus creating operational space to include, in the future, the reuse of paper and textile by-products as certifiable inputs.

This emphasizes how certification, far from being just a reputation badge, becomes a practical tool to support the circularity of materials; therefore, paying more attention to the by-products sector could help create more consistency in an area that remains too fragmented. From an economic standpoint, certifying by-

[292] See Commission Decision (EU) 2021/476 of 16 March 2021 'Establishing the EU Ecolabel Criteria for Hard Covering Products', with reference to Articles 2 and 7.

[293] With reference to the paper sector, see Commission Decision (EU) 2019/70 of 11 January 2019 (graphic paper); Commission Decision (EU) 2020/1803 of 27 November 2020 (printed paper products, envelopes, paper carrier bags, wrapping paper and stationery products); Commission Decision (EU) 2019/70 of 11 January 2019 (tissue paper and tissue products).

[294] See Commission Decision (EU) 2016/1349 of 5 August 2016 (footwear products) and Commission Decision (EU) 2014/350 of 5 June 2014 (textile products).

products through certification helps develop new market opportunities, boosting the competitiveness of companies that use advanced recovery practices.

The integration of by-products into certification schemes presents both a challenge and an opportunity: it demands refining regulatory and verification tools to prevent greenwashing, while also offering the chance to turn what appears to be production residue into a key for certified sustainability.

2.8 The Intersection between Intellectual Property and Circular Economy Law

2.8.1 Adapting Intellectual Property Rights to the Challenges of the Green and Circular Transition

The context of the green transition, in its vertical and horizontal multidisciplinarity, also prompts reflection on the role played by the evolution of intellectual property rights, traditionally viewed as the main driver of industrial development. The «New Action Plan for the Circular Economy» indeed emphasizes the need to revisit, in certain cases, the traditional categories of intellectual property rights to better align with the green transition[295].

So far, intellectual property rights are intended to serve their traditional role of safeguarding innovation and the rights of holders within a mostly linear economic system. As clearly stated in the 2020 Action Plan on Intellectual Property to Support the Recovery and Resilience of the European Union[296], it is a priority to

[295] See European Commission COM/2020/98 final. A *new Circular Economy Action Plan For a cleaner and more competitive Europe,* at §6.3, it is written: «The regime for intellectual property needs. to be fit for the digital age and the green transition and support EU businesses' competitiveness. The Commission will propose an Intellectual Property Strategy to ensure that intellectual property remains a key enabling factor for the circular economy and the emergence of new business models».

[296] See European Commission, Making the most of the EU's innovative potential: An intellectual property action plan to support the EU's recovery and resilience, COM/2020/760 final.

orient the regulatory framework relating to the protection of intellectual property so that it meets the needs of the green transition, first and foremost by considering the role that related instruments can play as promoters of innovation for the establishment of new production and consumption paradigms[297].

To date, intellectual property law is still based on utilitarian theories that exclude the value of sustainability[298] from the central structure of exclusive rights[299] , reducing it to a system of exceptions to be invoked only in extreme cases.

The resulting prejudice is structural and can be divided into at least three key aspects. First, the fact that sustainability issues are often seen as exceptions

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At § 1, the strategy says: 'Some of the most important social challenges of our times, such as making green transition possible or ensuring proper healthcare for all, cannot be addressed without innovative solutions. The development of renewable energy and low-carbon energy ecosystems, for instance, hinges on the rapid development and deployment of cutting-edge technologies, as well as effective tools for sharing critical intangibles, such as data. The development of a flourishing health ecosystem in Europe requires a transparent system of IP incentives, boosting innovation whilst ensuring effective access to affordable medicines. The cultural and creative sectors cannot thrive without effective IP protection. On this point, see B. SAUTIER, *With its IP action plan, the European Commission is stepping up its IP game,* in *Journal of Intellectual Property Law & Practice,* 2, 2021, pp. 107 ff., https://doi.org/10.1093/jiplp/jpab007

[297] See, M. LILLÀ MONTAGNANI, (*Digital) Circular Economy and IPRs: A Story of Challenges and Opportunities,* in *International Review of Intellectual Property and Competition Law,* 54, 2023, pp. 1009 ff. https://doi.org/10.1007/s40319-023-01359-y .

[298] About the interactions between IP Law and sustainability, reference is made to R. MELÉNDEZ-ORTIZ, P. ROFFE, *Intellectual Property and Sustainable Development,* Cheltenham, 2009; see also M. RIMMER, *Intellectual Property and Climate Change: Inventing Clean Technologies,* Cheltenham, 2011. See also, O. GONZALES, *IP in Times of Climate Crisis – A Problem or a Solution?,* in *International Review of Intellectual Property and Competition Law,* vol. 53, 2022, pp. 501 ff.

[299] By "exclusive intellectual property rights" are meant the powers granted to the holder of an intangible asset, which allow them to authorise or prohibit third parties from using the protected object. These rights confer a temporary monopoly and are subject to limits and exceptions, with varying durations.

makes the IP system somewhat inflexible. This hinders the current system's ability to adapt to environmental challenges, which require flexible tools capable of addressing problems that are in a state of constant evolution.

Moreover, the divergent interpretations of exceptions by different Member States, offices and courts engenders a fragmented and uncertain framework.

Moreover, it is important to acknowledge the prevailing perception of sustainability as a constraining factor rather than an opportunity.

However, it should be noted that the Treaties of the European Union establish a clear obligation to integrate environmental sustainability into all policies and activities of the Union, including the objective of achieving a high level of protection and improvement of the quality of the environment through the integration of the relevant requirements[300] .

Therefore, environmental requirements cannot be confined to specific areas of public law; they must also be considered in various fields of private law, with a particular emphasis on intellectual property. The development of the circular economy provides a valuable framework for analyzing the directions that European and national green public policies should pursue to turn action plans and strategies into concrete initiatives. This can be achieved through the adoption of strong

[300]As emphasised in doctrine, the Treaties of the European Union outline a clear obligation to integrate environmental sustainability into all Union policies and activities. Article 3(3) TEU stipulates that the Union shall work for the sustainable development of Europe, including a high level of protection and improvement of the quality of the environment. This principle is further confirmed in Article 11 TFEU, which requires environmental protection requirements to be integrated into the definition and implementation of all Union policies and activities. On this point, see T. PIHLAJARINNE, R.M. BALLARDINI, *Paving the way for the Environment: Channelling 'Strong' Sustainability into the European IP System,* in *European Intellectual Property Review,* 4, 2020, pp. 239 ff.

sustainability tools capable of balancing property rights and environmental protection[301] .

This context also includes the debate on the so-called *right to repair*[302] , recently relaunched at European level, which aims to guarantee consumers and independent repairers effective access to technical information and spare parts. It is important to note that this right, which is entirely consistent with the objectives of the green transition, risks coming into conflict with intellectual property rights. These rights, which include trademarks and patents, can be used to restrict the circulation of components, thereby hindering repair and reconditioning practices. The challenge lies in striking a balance between the imperative to safeguard innovation and the need to curtail the environmental repercussions of products by prolonging their life cycle.

[301] R.M. BALLARDINI, J. KAISTO, J. SIMILÄ, *Developing novel property concepts in private law to foster the circular economy,* in *Journal of Cleaner Production,* Volume 279, 2021, 123747, https://doi.org/10.1016/j.jclepro.2020.123747 .

[302] The reference is to Directive 1799/2024/EU, which Member States will need to transpose within twenty-four months of its entry into force. It contains common rules that promote the repair of goods and amends Regulation 2394/2017/EU and Directives 771/2019/EU and 1828/2020/EU. As emphasised in point 3) of the previous Commission Communication COM, 2023, 155 final, this directive would be necessary «in order to reduce the premature disposal of functional goods purchased by consumers and to encourage them to use these goods for longer; it is necessary to establish rules on the repair of such goods. Repair should translate into more sustainable consumption, as it is likely to lead to a reduction in waste from discarded goods, a lower demand for resources, including energy, for the manufacTorinog and sale of new goods that replace faulty ones, and a reduction in greenhouse gas emissions. This directive promotes sustainable consumption in order to generate benefits for both the environment and consumers, avoiding the costs associated with short-term new purchases».

This point has been reiterated in a multitude of court rulings. In this regard, a recent Norwegian ruling[303] examined the impact of trademark law on the circulation of refurbished products. The case involved Apple's claim of trademark infringement, which prevented an independent repairer from importing spare parts for iPhones. After an initial ruling in favour of the repairer, the Court of Appeal and the Supreme Court deemed the parts to be counterfeit, as they were composed of original elements bearing the Apple trademark, although not visible to consumers, together with non-original components.

Another significant aspect pertains to green patents, that is to say, instruments designed to protect technologies with minimal environmental impact. The dissemination of these systems has prompted numerous legal systems to contemplate the implementation of accelerated examination and granting procedures, colloquially designated as "fast tracks", to expedite their swift entry into the market.[304]. As pointed out in legal literature[305], however, their role in the circular transition remains largely unexplored, since these exclusive rights can also

[303] Supreme Court of Norway (Norges Høyesterett), decision of 2 June 2020 – HR-2020-1142-A. A comment on the sentence is postponed by K. STENVIK, *Importation of Goods Affixed with a Trademark Concealed by a Removable Marker,* in *GRUR International,* vol. 70, 2021, pp. 285 ff.

[304] On this point, please refer to V. IAIA, *Gli eco-brevetti tra neutralità tecnologica e (sensibilità) climatica,* in *Rivista di Diritto Industriale,* 2, 2020, pp. 88 ff. For a general overview on the role of patents in green transitions, reference is made to E. DERCLAYE, *Should patent law help cool the planet? An inquiry from the point of view of environmental law - Part I*, in *EIPR,* vol. 31, 2009, pp 168 ff. For a general overview, it is also important to emphasise the existence of the "green patent paradox", a radical theory according to which the patent system in fact hinders innovation, allowing rights holders to entrench themselves in their patents, thereby further slowing the transition towards a sustainable economy. See, for example, S. CAYTON, *The 'Green Patent Paradox' and Fair Use: The Intellectual Property Solution to Fight Climate Change, in Seattle Journal of Technology, Environmental & Innovation* Law, 1, 2020, pp. 214 ff.

[305] See L. ZOBOLI, *Il sistema brevettuale e la "transizione verde" verso l'economia circolare,* in *Giurisprudenza commerciale,* 2, 2024, pp. 447 ff.

hinder the repair of patented products, even if in principle, permitted by the doctrine of exhaustion, unless it involves substantial modifications.

Undoubtedly, patent protection, if properly targeted, can become a driving force for promoting *R activities* (repair, reuse, regeneration, recycling) typical of circularity contexts. This requires the adoption of appropriate procedural and substantive measures and, above all, the introduction of a clearly defined limitation on patent rights, allowing secondary use of products already placed on the market without compromising the protection of the rights holders.

Unlike patents (which require the disclosure of the invention in exchange for an exclusive right), the protection of know-how is based on confidentiality and trade secrets[306] . The maintenance of exclusive advantages in terms of knowledge, as well as greater flexibility in its application, is facilitated by trade secrets, due to the non-application of patent procedures.

In the context of ecological transition, however, certain aspects could undermine the very idea of spreading circularity models. For example, total confidentiality of know-how could conflict with the principle enshrined in Article 11 TFEU, which requires environmental protection requirements to be integrated into all Union policies and actions. From this perspective, therefore, there is an increasing need for the organisational paradigm of open innovation[307] which, through cooperative models and technology exchange platforms, promotes the

[306] Directive 943/2016/EU has introduced a harmonised regulation at the European level regarding trade secrets, defining them as confidential information, having economic value, and protected by appropriate confidentiality measures. It provides for both civil remedies (injunctive measures, damages, corrective actions) and procedural protections (protection of confidentiality during legal proceedings), balanced by exceptions such as lawful reverse engineering, independent discovery, and use for purposes of public interest. The directive has thus bridged national divergences, strengthened the competitiveness of the internal market, and outlined know-how as a strategic asset of European intellectual property.

[307] H. CHESBROUGH, *Open innovation: The New Imperative for Creating and Profiting from Technology,* Harvard Business School Press, 2003.

controlled circulation of technical knowledge between businesses, universities and public institutions. This approach enables balancing private economic interests with the public goal of expanding sustainable solutions, lowering access costs to green technologies, and fostering an innovation ecosystem aligned with circular economy principles.

2.7.2 Defining the Scope and Limits of Intellectual Property in the By-Products Sector

Various innovative processes that utilize production residues can create technical solutions, usage models, or material compositions eligible for patent protection or trade secrets as industrial know-how. This demonstrates a cycle where new technical and technological knowledge can be created. In other words, the valorization of production residues results directly from all the challenges summarized in the previous paragraph, which aim to restore the delicate balance between strong sustainability and the protection of intellectual property in the industrial world.

While the patenting of by-product transformation processes may confer a competitive advantage upon the patenting company, it is important to note that excessive protection through exclusive rights may impede the dissemination of virtuous industrial symbiosis practices (e.g. the reuse of by-products), which are frequently associated with knowledge-sharing models.

This principle similarly applies to techniques for treating and valorising by-products that are not patented but rather protected as confidential company know-how.

This raises valid questions about transparency and traceability: the challenge of distinguishing between information protected by secrecy and data needed to demonstrate a material's classification as a by-product could, in fact,

serve as a barrier to both public authority controls and the development of open and competitive markets.

In this context, the example of by-products in intellectual property helps us expand discussions on promoting hybrid models that encourage the adoption of open innovation practices and compulsory licenses for green technologies.

The following chapter therefore aims to transpose these issues into the context of plant-based by-products, in order to verify the extent to which the legal categories analysed are adequate for governing flows characterised by a dual dimension, both environmental and food-related. In this way, the transition from the general to the sectoral level makes it possible to test the resilience of the existing regulatory framework and to identify, in more concrete terms, the scope for adaptation and legal innovation necessary to promote the effective circular valorisation of by-products in the agri-food system.

Chapter 3: Plant-Based By-Products and the Circular Bioeconomy in the Agri-Food System

3.1 Agri-Food By-Products in the Food Circular Economy: Between Law, Policy, and Science

After outlining the general characteristics, critical issues of interpretation, and legal prospects for the broader category of by-products, we then focus on a specific area of investigation: the use of by-products in the agri-food industry.

The initial analysis showed that this institution has significant potential for industrial symbiosis based on the circular economy. However, there is still a need for a thorough review of the institution and its improved integration within the European Union's toolkit to facilitate systemic transition.

As outlined in the first chapter, one of the most complex transition processes involves the interactions between the circularity paradigm and food sustainability, presenting a particularly difficult challenge for policymakers, legislators, and STEM experts.

In this context, food production residues serve as a tangible example of systemic tension, as they highlight and emphasize the structural issues inherent in the category of by-products: from definitional uncertainties (internal and cross-border) to risks faced by entrepreneurs operating in uncertain conditions, from the need to be valued through ecologically focused economic instruments to challenges related to industrial property in the face of ecological emergencies.

In addition to this, other critical issues must be considered. Firstly, agri-food waste is highly perishable, so rapid logistics and storage solutions are required for reuse. Another issue is the challenge of ensuring proper traceability and compliance with food safety standards. Finally, the socio-cultural acceptance of products made from food waste is equally important, as this inevitably influences companies' production decisions in the sector.

The valorisation of agri-food production residues adds further complexity to a discipline that is difficult to define and systematise, even in its general features. After outlining the legal framework for all types of by-product, the analysis focuses on the critical issues specific to institutions in the agri-food sector.Regarding food resources, it is important to highlight the existence of a food hierarchy[308] that serves as a sector-specific version of the waste hierarchy discussed earlier. At the European and international levels, this hierarchy is depicted in the following figure.With regard to food resources in particular, it is important to emphasise the existence of a food hierarchy, which can be considered a sector-specific version of the waste hierarchy explained in the previous chapter. The following figure illustrates this hierarchy at the European and international level.[309]

[308] E. PAPARGYROPOULOU, R. LOZANO, J.K. STEINBERGER, N. WRIGHT, Z. UJANG, *The Food Waste Hierarchy as a Framework for the Management of Food Surplus and Food Waste*, in *Journal of Cleaner Production*, 76, 2014, pp. 106 ff.

[309] J. SANCHEZ LOPEZ, C. CALDEIRA, V. DE LAURENTIIS, S. SALA, *Brief on food waste in the European Union,* M. AVRAAMIDES (ed.), European Commission, Joint Research Centre (JRC121196), Luxembourg: Publications Office of the European Union, 2020, doi:10.2760/415788

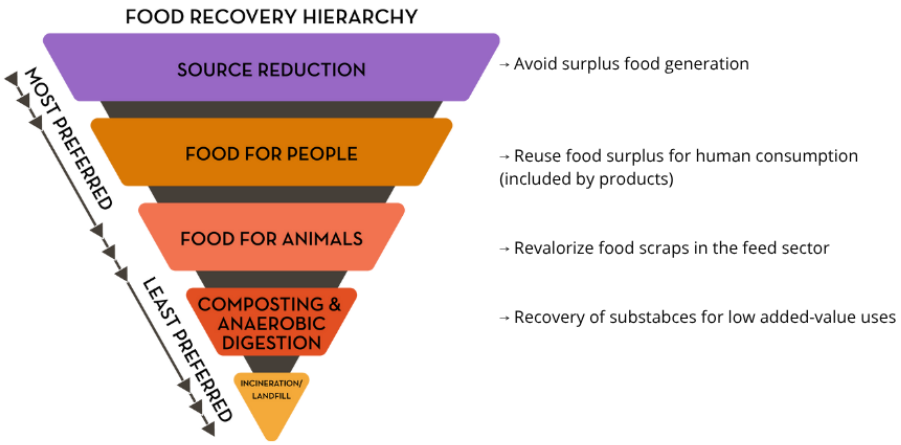

Figure 1 Food hierarchy example

As shown in Figure 1, the principle of prevention remains essential in managing food resources, ensuring no overproduction occurs. In this hierarchy, food by-products are vital and provide unmatched flexibility in their use.

This example clearly highlights the urgent need to review the legal status of the institution at the European level to strengthen a strategic single market for the promising new European industrial sector.

The issue illustrates a concrete example of the food circular economy and its effects between organic and inorganic components, as can be inferred from the observations made by the MacArthur Foundation[310].

Reading this butterfly diagram from an agri-food perspective highlights the intrinsic interconnection between biological and technical flows in this sector.

Agri-food by-products embody this intersection, as they can either follow the so-called «biological trajectory» (returning to the food cycle as ingredients, feed, or fertilisers) or the so-called «technical trajectory» (thus taking on the role of raw materials, especially in the packaging sector).

[310] Please refer to https://www.ellenmacarthurfoundation.org/circular-economy-diagram

Reorienting agrifood scraps between cycles should rely on objective criteria to uphold the food hierarchy and meet the needs of the integrated One Health approach.

In this sense, any legal observation made there is connected to the importance of impact measurement tools. Legal decisions about reusing and valuing agri-food residues need to balance environmental impact assessments with socio-economic needs. Thus, tools such as Life Cycle Assessment (LCA)[311] and Life Cycle Costing (LCC)[312] take on a strategic role, providing a strongly empirical basis for circular economy policies and creating a testing ground for the evolution of evidence-based law.

Always approaching from a scientific perspective, another notable example is the FoodWaste Explorer[313], a digital platform managed by the Joint Research

[311] The *Life Cycle Assessment* (LCA) methodology is internationally standardised in ISO 14040 and 1404471. Specifically, it is a method aimed at assessing and quantifying energy and environmental loads as well as potential impacts associated with a product/process/service throughout its entire life cycle, *from cradle to grave.* On this point, see G. L. BALDO, S. ROLLINO, G. STIMMEDER, M. FIESCHI, *The Use of LCA to Develop Ecolabel Criteria for Hard Floor Coverings on Behalf of the European Flower,* in *Int J LCA,* 7, 2002, pp. 269 ff.

[312] Life Cycle Cost (LCC) refers to the *total cost of ownership* of an asset over its entire life span — from design and acquisition to operation, maintenance, and end-of-life disposal. It provides a long-term economic perspective, enabling decision-makers to compare different options not only by their purchase price but by their *total cost efficiency* over time. In sustainability and public procurement, LCC is essential to ensure that resources are allocated to solutions that are both economically and environmentally optimal. Incorporating Life Cycle Costing helps prevent short-term savings that lead to higher operational or maintenance costs later on, thereby supporting a more sustainable and cost-effective decision-making process. On this point, see P. GLUCH, H. BAUMANN, *The life cycle costing (LCC) approach: a conceptual discussion of its usefulness for environmental decision-making,* in Building and Environment, 5, 2004, pp. 571 ff. https://doi.org/10.1016/j.buildenv.2003.10.008 .

[313] Among the scientific and technical tools developed at the European level to support the transition towards a sustainable and circular food system, the FoodWaste Explorer, created by the

Centre (JRC) of the European Commission. It is the only open and harmonised database to facilitate a consistent scientific characterization of food waste and by-products. Scientifically, the platform documents residues and aims to create an empirical foundation for developing future technical and regulatory standards.

Joint Research Centre (JRC) of the European Commission, stands out as a pioneering example. It is an open-access and harmonised database designed to collect, validate, and classify scientific information on food waste and by-products generated across different stages of the agri-food supply chain. Its primary objective is to provide a detailed map of the biochemical, nutritional, and technological composition of residual materials, in order to support their reuse within a circular framework. Each entry in the platform describes the nature and properties of the material — whether it concerns grape pomace, fruit peels, seeds., olive cake, bran, cereal residues, agro-industrial sludge, or other by-products — including data on macronutrients, fibres, bioactive compounds, metals, contaminants, and technologically relevant components. This cataloguing system allows the potential uses of each material to be identified in multiple sectors, ranging from food and feed production to cosmetics, green chemistry, biogas and bioplastic production, and organic fertilisers. The FoodWaste Explorer represents one of the first examples of a European knowledge infrastructure specifically devoted to the valorisation of agri-food residues. It translates the idea that waste should not be considered merely as discarded matter but as a carrier of information and potential value, to be analysed, classified, and reintegrated into new productive cycles. By standardising and validating scientific data, the platform helps establish a common language between science, industry, and institutions, making it possible to design policies based on reliable evidence. In this sense, it functions as a tool of cognitive governance, where the management of food residues becomes both a scientific and regulatory process grounded in empirical knowledge. From a methodological perspective, the FoodWaste Explorer is structured as an open-access database organised into analytical sheets and comparative tables. Each sheet results from a process of data collection and validation, based on information drawn from scientific literature, technical reports, and experimental analyses, which are then harmonised according to criteria established by the JRC.This ensures the reliability and comparability of data, enabling researchers, businesses, and policymakers to access coherent and structured information within a shared European framework. Its data-driven approach makes the platform a technical cornerstone of the evidence-based circularity paradigm, in which sustainability is no longer a merely political goal but a quantifiable and verifiable process. See, https://www.foodwasteexplorer.eu/

Despite its significant potential, the platform has notable limitations. For instance, it handles plant matrices fragmentarily and does not offer a comprehensive view of local, artisanal, or non-standardized food supply chains.

Additionally, the tool offers a summary of the chemical, analytical, and nutritional aspects of such substances, explicitly omitting economic, logistical, or legal factors. It is important to note that there is no direct link between scientific profiles and regulations, which, for instance, determine the legal status of by-products or waste, as well as the specific safety and environmental standards for reuse.

Reporting this concrete example highlights the extent of the work remaining to address the fragmentation of challenges associated with the circular transition. It also underscores the necessity to redefine governance and enforcement models within the agri-food system.

3.2 Typologies of By-Products in the Agri-Food Sector

3.2.1 Regulatory Disparities between Animal-Based and Plant-Based By-Products

To establish some initial guidelines, the topic of agri-food by-products should be divided into two categories: by-products of animal origin and by-products of plant origin.

This is because only by-products of animal origin[314] are subject to specific regulations, due to an uneven regulatory framework.

[314] Animal by-products (ABPs) refer to materials of animal origin that are not intended for human consumption, either by nature or by decision of the operator. They encompass a broad spectrum of substances generated along the agri-food chain — including non-edible parts from slaughtered animals (such as skins, bones, blood, and offal), carcasses of animals that die on farms

Specifically, Regulation 2009/1069/EC[315] regulates this area by providing classifications, risk assessments and usage guidelines for animal by-products not intended for human consumption.

This regulation is an important tool for achieving integrated governance, where health and environmental regulations interact with each other. In other words, the management of animal by-products is not confined to a single sector, but is linked to a broader framework geared towards sustainable production chains. It has three main strengths.

Critical issues arise when implementing a single market for by-products, and this regulation marks a significant move towards EU-wide harmonization by establishing a consistent and directly applicable set of rules. This avoids regulatory fragmentation and arbitrage among Member States. In line with the subsidiarity principle, it exemplifies how regulatory consistency in technically and scientifically complex sectors enables the EU to guarantee uniformity. The aim is to prevent competition distortions while supporting a safe and sustainable agri-food chain.

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or as pets, as well as materials produced by animals (e.g., manure, feathers, wool, beeswax, eggshells). The definition also extends to former foodstuffs of animal origin that, for commercial, quality, or technical reasons, are no longer suitable for human consumption. In the EU, over 20 million tonnes of ABPs are produced every year from slaughterhouses, industries producing food for human consumption, and fallen stock from farms.

[315] Complementing this, Commission Regulation 2011/142/EU provides the implementing measures for Regulation 1069/2009. It defines technical standards for processing (e.g., sterilisation temperatures, pressure and time parameters), conditions for placing products on the market, import/export rules, and criteria for determining when certain derived products have reached a safe "end point" and are no longer subject to Animal By products legislation. Among scholars, see R. LEOCI, *Animal by-products (ABPs): origins, uses, and European regulations,* Universitas studiorum, Bologna, 2014.

The regulation addresses animal by-products through the adoption of proportionate, risk-based measures[316]. These measures allow the treatment, transport, storage, and use of by-products to be adapted according to the assessed level of risk, ensuring a highly technical and proportionate approach in accordance with the latest technological advances in the field of scraps' recovery.

Furthermore, the regulation encourages the shift towards circularity in the food and feed sector, highlighting that, within safety limits, production cycles can be viewed as closed loops due to the transformation of animal by-products into energy, fertilizers, or new materials.

Although it is a vital part of the organic circular economy mosaic, this regulation faces significant challenges. The main issue is that it relies on evaluating an institution - the valuation of by-products- which has vague regulatory limits and different frameworks in various countries, as explained earlier.

These issues are further exacerbated by the multiple levels of control, leading to increased procedural complexity. Consider, for example, the overlap between health protection authorisations and environmental protection authorisations. This creates numerous obligations for economic operators.

[316] EU law, developed with EFSA's scientific advice, classifies ABPs into three categories according to potential risks to public and animal health (highest risk: Category 1; intermediate: Category 2; lowest: Category 3). This classification determines permitted uses (e.g., only certain Category 3 materials may enter feed chains) and required processing/disposal routes. EFSA supports the system by assessing risks of ABPs and of new or alternative processing methods (e.g., for biodiesel co-products, alkaline hydrolysis, or thermal treatments), which can then be incorporated into the legislation if deemed safe. Robust traceability, separation of categories, and validated processing parameters are essential controls to prevent disease transmission (including TSEs) while enabling safe valorisation into products such as fertilisers, biofuels, cosmetics, or specific feeds.. EFSA's role extends to evaluating when "end points" are reached -stages at which derived products can exit the ABP rules because risks are considered controlled.

Ultimately, while Regulation 1069/2009/EC has established a harmonized framework (though somewhat problematic in certain areas) for effectively managing animal by-products, the same cannot be said for plant by-products.

This regulatory imbalance inevitably causes systemic disruptions, tying the management of plant-based by-products to a scattered array of fragmented and sector-specific rules, ultimately undermining their economic value.

Attention is being focused on plant-based by-products due to their growing bioeconomic potential. The aim is to improve the efficiency of circular supply chains and reduce the negative externalities resulting from agro-industrial emissions.

For example, in the fruit and vegetable sector alone, industrial processing generates 25–30% of potential by-products, such as peels, seeds, pomace, fibrous residues, and waste pulp.

Failure to reuse them results in the loss of considerable multifunctional potential, ranging from bioenergy production to developing innovative biomaterials and extracting bioactive compounds for use in various industries (e.g. pharmaceuticals and cosmetics).

From this perspective, the lack of European regulations is increasingly outdated, leading to a weakening of the Union's bio-circular governance. In this context, it is appropriate to identify several strategic actions that could enhance the consistent and rational use of plant by-products within the Union.

A key initial step is to clearly define by-products of plant origin from a legal perspective, distinguishing them from waste and by-products of animal origin.

This would help to standardise interpretative difficulties associated with this category, reducing the need to refer to different national regulations and European waste legislation.

At the same time, developing technical glossaries with the support of the Joint Research Centre and the European Food Safety Authority (EFSA) would

significantly improve understanding of plant-based by-products within the agro-industrial sector.

Inspired by the rules applied to animal by-products, plant-based by-products could also be classified according to risk, such as phytosanitary, environmental, or food safety risks, in line with criteria provided by biological science experts.

Furthermore, such regulation could establish a comprehensive, integrated traceability system that ensures consistency with food safety and industrial emissions regulations, as well as across different sectors.

Greater attention to this issue would positively impact the Union's green policies, creating a more favourable environment for using public funds to support bio-sustainable production solutions.

While advocating for new European legislation on this matter, attention should also be directed towards the existing regulatory framework, to reconstruct a functional, albeit fragmented, legal system that fosters the immediate and coherent use of plant by-products within the agro-industrial sector.. The existing legal framework must be interpreted using the One Health approach, the food waste hierarchy, and the principle of circularity.

In the context of industrial symbiosis, these aspects also highlight the growing need to support SMEs, which according to official data account for around 90% of the European agri-food production system. A clearer, more coherent regulatory framework would encourage their active participation in the bioeconomic landscape and promote the development of widespread innovation ecosystems.

Moreover, the valorisation of plant by-products not only reduces environmental impact and protects consumer food safety, but also offers the opportunity to implement structural inclusion mechanisms for a fair, resilient, territory-oriented circular transition.

3.2.2 Reconstruction of the Existing Regulatory Framework for Plant-Based By-Products in the Perspective of Circular Economy"

Both the "Circular Economy Action Plan" and the "Farm to Fork" strategy emphasise the potential of plant waste streams for producing innovative bioproducts, bioplastics, and biomaterials. Furthermore, in the context of the agricultural sector, plant-based by-products play a core role in the Common Agricultural Policy (CAP)[317] and its regenerative eco-schemes.

[317] A key instrument for achieving the above objectives is the new Common Agricultural Policy (CAP) for the period 2023-2027, which aims to steer European agriculture towards the principles of the Green Deal through a system of direct payments, sectoral interventions and rural development measures coordinated in National Strategic Plans (with a view to a system of shared competence between Member States and the EU). The support provided by the CAP to European agriculture is an example of the renewed importance of public intervention in the current economic scenario. The main CAP-related interventions include income support measures for farmers, market measures to deal with sudden fluctuations in the sector, and rural development measures. The CAP is financed by two funds within the EU budget: the European Agricultural Guarantee Fund (EAGF) - which provides direct support and finances market measures - and the European Agricultural Fund for Rural Development (EAFRD). From a strictly legal standpoint, the Common Agricultural Policy (CAP) represents a crucial area of EU legislation. Its main legal basis is found in Articles 38 to 44 of the Treaty on the Functioning of the European Union (TFEU). For the purposes of this discussion, it is sufficient to note that Article 38(1) states ‹‹*The Union shall define and implement a common agriculture and fisheries policy*››, while Article 39 sets out its specific objectives. These objectives are closely linked to various economic, social, and environmental goals recognized by the TFEU: the promotion of employment (Article 9), socio-economic cohesion (Articles 174-178), environmental protection within a framework of sustainable development (Article 11), animal welfare (Article 13), and human health (Article 168). The most recent reform of the Common Agricultural Policy (CAP), covering the period 2023-2027, is based on a renewed legal and operational framework established by three key regulations, all adopted on December 2, 2021. Together, they define the new direction of the CAP, aligning it more closely with sustainability, efficiency, and flexibility goals. The Regulation 2116/2021/EU focuses on the financing, management, and monitoring of the CAP. It replaces Regulation 1306/2013/EU and introduces

While the Waste Framework Directive does not explicitly address plant-based by-products, it provides the main framework for their classification. Clearly, plant residues that meet the well-known criteria in the context of agro-industrial processes can be classified as by-products, provided they are reused, comply with standard industrial practices, and do not harm the environment or health.

To supplement this observation, various EU measures can be implemented. One example is Regulation 2019/1009/EU[318] on fertilising products in the Union,

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updated mechanisms for ensuring greater transparency and accountability in the use of EU agricultural funds. The Regulation 2021/2115/EU lays down the rules for the design and implementation of National Strategic Plans by Member States. These plans are the core instruments through which countries tailor CAP interventions to their specific needs., backed by financial support from the European Agricultural Guarantee Fund (EAGF) and the European Agricultural Fund for Rural Development (EAFRD). This regulation repeals Regulations 1315/2013/EU and 2013/1307/EU, which previously governed rural development and direct payments. Lastly, the Regulation 2021/2117/EU amends several sectoral regulations to ensure coherence across EU agricultural law. It updates: Regulation 2013/1308/EU, which establishes a common organization of agricultural markets; Regulation 2012/1151/EU, on quality schemes for agricultural products and foodstuffs; Regulation 2014/251/EU, concerning the labeling and protection of geographical indications for aromatized wine products; Regulation 2013/228/EU, which sets out specific measures for agriculture in the EU's outermost regions. For a reconstruction of the evolution of the CAP, reference is made to A. GERMANÒ, E. ROOK BASILE, *Manuale di diritto agrario comunitario*, Giappichelli, Torino, 2014, pp. 232 ff. See, also, N. RÖDER, C. KRÄMER, R. GRAJEWSKI, S. LAKNER, A. MATTHEWS *What is the environmental potential of the post-2022 common agricultural policy*?, in *Land Use Policy*, 144, 107219, 2024; D. CARLONI, *La «nuova» politica agricola comune sotto accusa: le ragioni degli agricoltori in rivolta*, in *Diritto e Giurisprudenza Agraria dell'Alimentazione e dell'Ambiente*, 1, 2024, pp. 1 ff: P. LATTANZI, *Il New Green Deal, la PAC 2021-2027 e la sostenibilità nelle produzioni alimentar*i, in P. BORGHI, I. CANFORA, A. DI LAURO, *Trattato di diritto agroalimentare italiano e di diritto europeo*, Giuffré, Milano, 2021, pp. 711 ff.; V. RUBINO*, La sostenibilità in agricoltura e la riforma della PAC*, Cacucci, Bari, 2021, pp. 202 ff.

[318] Annex II of the EU Fertilising Products Regulation defines the Component Material Categories (CMCs), which establish the types of materials that can be used in the manufacture of EU-labelled fertilising products. This annex plays a key role in broadening the scope of acceptable

which permits organic by-products (including those of plant origin) to be used as components of European fertilisers, provided they meet the necessary safety, traceability, and agronomic quality standards. In other words, this explicitly recognizes the potential to valorise plant-based residues as production inputs within a closed-loop approach for soil regeneration[319].

Another element of the regulatory mosaic is Directive 2018/2001/EU (known as RED II)[320], which promotes the use of energy from renewable sources

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input materials, promoting the valorisation of by-products and secondary raw materials within the European circular economy. Through categories such as CMC 6 (Food industry by-products) and CMC 11 (By-products within the meaning of Directive 2008/98/EC), the Regulation explicitly recognises the potential of organic residues and by-products from agri-food industries, including those of plant origin, to be safely reintroduced into production cycles as valuable components for fertilising products. Furthermore, CMC 3 (Compost), CMC 4 and 5 (Digestate), and CMC 10 (Derived products under Regulation (EC) No 1069/2009 on animal by-products) demonstrate the Regulation's integrated approach to resource recovery and waste reduction, ensuring that such materials meet strict safety and quality standards before being placed on the market.In essence, Annex II operationalises the EU's commitment to sustainable nutrient management, fostering innovation in the use of both animal- and plant-based by-products from the agri-food sector, while maintaining a high level of protection for human health and the environment.

[319] On this topic, see A. DEPIETRI, *The Sustainable Use of Healthy Soil as a Cornerstone of the One Health Approach: An Analysis of European Public Strategies and Market-Based Environmental Protection Tools,* in G. ANTONELLI, F. PENNA, E. CHATURVEDI, A. CILENTO (eds.), *Planetary Health - Laws, Policies and Science on the 'One Health' Approach, cit,* pp. 19 ffhttps://doi.org/10.1007/978-3-031-90621-3_2

[320] The Directive establishes the legal framework for the production and use of renewable energy within the European Union, and places strong emphasis on the sustainable use of biomass derived from both animal and plant sources. Throughout its recitals, articles, and annexes, the Directive makes clear and repeated references to agricultural residues, waste, and by-products, thereby including vegetal by-products generated within the agri-food and agricultural sectors. Specifically, Article 2 defines *biomass* as «the biodegradable fraction of products, waste and residues of biological origin from agriculture (including vegetal and animal substances), forestry and related industries», thus explicitly integrating materials of vegetable origin within the concept of renewable

and gives plant-based by-products from agriculture and the food industry a significant role in developing sustainable biomass. This aspect ties the valorization of organic plant flows to the broader energy transition.

Furthermore, shifting focus to the feed sector, it should be noted that Regulation 2009/767/EC[321], which concerns the placing on the market and use of

biomass. Article 29 further regulates the sustainability criteria for biofuels, bioliquids, and biomass fuels obtained from such sources, establishing that residues and by-products from agricultural biomass can be used for renewable energy purposes provided that they meet the relevant greenhouse-gas emission saving and sustainability thresholds. In addition, Recital (37) of the Directive recognises the importance of utilising *waste and residues* and cautions against creating «unnecessary distortions of markets for (by-)products, waste or residues». This acknowledgement confirms the legislator's intent to include by-products — both vegetal and animal — within the renewable energy value chain, underlining their potential for sustainable valorisation. The connection is further reinforced in Annex IX, which lists eligible feeds.tocks for the production of advanced biofuels and biogas. This Annex explicitly mentions residues from agriculture, aquaculture, fisheries and forestry, as well as various processing residues of plant origin (e.g., straw, husks, nutshells, corn cobs, and other lignocellulosic materials). These examples clearly demonstrate the Directive's recognition of vegetal by-products as legitimate and valuable raw materials for renewable energy generation.
Taken together, these provisions show that Directive 2018/2001 not only establishes the legal foundation for the use of plant-based by-products and residues in energy production but also promotes their integration into the broader EU strategy for circular bioeconomy and resource efficiency. The Directive thus supports a model of sustainable growth where agricultural and agri-food by-products — once treated as waste — become essential inputs for renewable energy, reducing environmental impact and enhancing the EU's energy independence.

[321] It offers a comprehensive legal framework for the valorisation and safe use of vegetal by-products within the European feed sector. It recognises that a wide array of materials of plant origin, including those derived from agricultural and agro-industrial processes, may legitimately be used as feed materials, provided they meet defined safety and compositional standards.
Although the Regulation does not present an exhaustive list of eligible materials, Annex I and Annex II explicitly reference numerous examples of plant-based products and by-products. These include, among others:

- Cereal derivatives such as *wheat bran, maize gluten feed, barley middlings, and rice bran*, which are residues from milling and starch extraction processes.

feed, includes agri-food products and by-products (including those of plant origin) among raw materials, provided they meet EU safety and traceability standards.

Together, the above provisions represent the initial steps toward a revitalized plant-based bioeconomy. They pave the way for a waste management approach that is closely integrated with energy, agricultural, industrial, and climate

- Oilseed and oleaginous fruit residues, for instance *rapeseed meal, soybean meal, sunflower seed cake, linseed expeller, and cottonseed meal*, generated after oil extraction.
- Tubers and roots by-products, including *dried potato pulp, beet pulp, and tapioca residues*.
- Fruit and vegetable processing by-products, such as *citrus pulp, tomato pomace, apple pomace, grape marc, and sugar beet molasses*, which are rich in fibre, sugars, and micronutrients.
- Other vegetal materials, like *legume husks, pea hulls, and brewer's spent grains*, derived from food, beverage, and fermentation industries.

By incorporating such by-products within its legal scope, the Regulation performs a dual function: it acknowledges their nutritional and economic value while simultaneously ensuring their safety and quality through clear analytical standards. Parameters such as crude protein, crude fibre, starch, moisture content, and ash levels are defined to guarantee that these materials are suitable for animal consumption and consistent with overall feed safety objectives.

From a broader policy perspective, this legal framework aligns closely with EU priorities on circular economy and bioeconomy development. By establishing that vegetal residues and co-products from agricultural and food processing activities may be lawfully marketed as feed materials, the Regulation enables their reintroduction into productive cycles, reducing waste generation and dependence on virgin resources. Furthermore, it supports industrial symbiosis across agri-food systems: by connecting feed manufacturers with upstream agricultural and food industries, it promotes resource efficiency, waste prevention, and the cascading use of biomass. In doing so, it also contributes to EU strategies on sustainable food systems, waste reduction, and climate neutrality. In essence, Regulation functions as a cornerstone of European legislation facilitating the safe, efficient, and sustainable valorisation of vegetal by-products. By explicitly listing and regulating materials such as wheat bran, oilseed cakes, beet pulp, citrus pulp, and tomato pomace, it provides a robust normative foundation for integrating plant-based secondary resources into circular value chains, advancing both economic and environmental objectives within the agri-food sector.

policies. This also presents an ongoing challenge for the future of European environmental law.

3.3 Reconstructive Perspective: Integrating Plant-Based By-Products between Biological and Technical Cycles in the Food Circular Economy

3.3.1 The Role of Food Upcycling in the Valorisation of Plant-Based By-Products: Opportunities and Challenges

From what has emerged so far, it is clear that the fragmented European framework related to plant by-products does not manage to cover all the steps of the food hierarchy previously outlined. Currently, plant by-products can be reused in various biological circularity processes (such as energy conversion, soil regeneration, and feed industry) and, as we will see later, in technical flows.

Therefore, the focus should be on thoroughly analyzing the role of vegetable by-products in human nutrition to explore new ways of reusing these materials within the evolving agri-food production industry.

This aspect intersects with the practice of *food upcycling*[322], which is not yet developed in the legal field but is fundamental in the context of the food circular economy.

In 2020, Harvard University's renowned Upcycled Food Definition Task Force[323] proposed a shared and operational definition: food upcycling practices

[322] J.ASCHEMANN-WITZEL, D. ASIOLI, M. BANOVIC, M. A. PERITO, A. O. PESCHEL, V. STANCU, *Defining upcycled food: The dual role of upcycling in reducing food loss and waste*, in *Trends in Food Science & Technology*,Vol. 132, 2023, pp. 132 ff.

[323] UPCYCLED FOODS DEFINITION TASK FORCE, *Defining Upcycled Foods,* University of Harvard, 2020 https://chlpi.org/wp-content/uploads/2013/12/Upcycled-Food_Definition.pdf; See

create new products intended for human consumption[324]. The conditions for these products vary and relate to the safe reintroduction of items, in the form of ingredients, that would otherwise have been discarded as waste. Additionally, upcycled food products must provide added nutritional value, be meant for human consumption, and meet the usual traceability standards of the sector.

To illustrate this concept, here are some examples of food upcycling transformations[325]: in the bakery and supplement sector, grape skins and seeds and brewer's spent grain can be reused in functional flours; additionally, tropical fruit pulp and skins (e.g., mango or pineapple) can be turned into dehydrated purée or natural additives for the confectionery industry; in the probiotic beverage sector, waste from general fruit and vegetable processing can be used as fermentation substrates.

In this context, it is evident that plant-based by-products can play a key role in promoting ethical production and consumption practices, integrating food safety standards and technological advancements. The development of these practices naturally influences the right of the Union and Member States to reconsider legal definitions and food safety limits in a circular manner[326].

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also O. SPRATT, R. SURI, J. DEUTSCH, *Defining Upcycled Food Products*, in *Journal of Culinary Science & Technology*, *19*(6), 2000, pp. 485 ff https://doi.org/10.1080/15428052.2020.1790074

[324] For a general overview of the food upcycling market, see H. YE, Emerging Trends in Sustainable Marketing*: A Review of Upcycled Food Research and Opportunities for Growth*, in *Journal of Sustainable Marketing*, X(X), 2023, pp. 1 ff. https://doi.org/10.51300/JSM-2023-104; J. ASCHEMANN-WITZEL, D. ASIOLI, M. BANOVIC, *Defining upcycled food: The dual role of upcycling in reducing food loss and waste,* in *Trends in Food Science & Technology,* 132, 2023, pp. 132 ff. https://doi.org/10.1016/j.tifs.2023.01.001

[325] In the technical scientific literature, there are many examples of the results achieved. See, for example, S. SEHGAL, B. SINGH, V. SHARMA (eds.), *Smart and Sustainable Food Technologies.* Springer, Singapore, 2024, https://doi.org/10.1007/978-981-19-1746-2_13.

[326] Among the very few legal and scientific contributions on the subject, reference is made to M. RAO, A. BAST, A. DE BOER, *Valorized Food Processing By-Products in the EU: Finding the*

In this context, the lack of a harmonized framework creates several legal grey areas, as European legislation does not explicitly address plant-based by-products intended for human consumption in the main EU acts, such as those covering food safety, contaminants, and microbiological requirements.

This initial consideration leads to several reflections. The issue of food safety is harmonized at the European level by Regulation 2002/178/EC (renamed General Food Law)[327], which primarily addresses definitions, principles, the responsibilities of food business operators, and risk management. Surrounding this core legislation, there are specialized regulations focusing, for example, on food hygiene, contaminants, and food controls.

However, the framework underlying all food legislation is based on a strictly linear logic that does not explicitly accommodate the valorization of food derived from residual streams, such as by-products. This creates a significant gap between the law and industrial practices, where new technologies and supply chains aim to operate in a circular manner[328].

Balance between Safety, Nutrition, and Sustainability, in *Sustainability* 13, 2021, pp. 428 ff. https://doi.org/10.3390/su13084428

[327] B.M VAN DER MEULEN, *The System of Food Law in the European Union, in Deakin Law Review,* 14(2), pp. 305 ff. See, also M. RAMAJOLI, *La giuridificazione del settore alimentare*, in *Diritto Amministrativo*, 4, 2015, pp. 657 ff. At page 660, the Author stated that the Regulation «Although it specifically refers to food safety, it is conceived as general food legislation and, as such, is a framework law to be complied with when subsequent regulations are adopted by both the European Union and individual Member States (Article 4). It has multiple objectives, namely ensuring a high level of human protection and consumer interests in relation to food. Particular consideration is given to the diversity of the food supply, including traditional products, while ensuring the functioning of the internal market (Article 1)». (Free translation)

[328] The linear nature of the European food law framework can be traced directly to the General Food Law Regulation, whose architecture was designed to ensure food safety rather than to promote the recovery or re-use of food materials. The Regulation's main provisions, such as Article 1, which defines the objective of safeguarding human health and consumer interests, and Article 14, which prohibits the placing on the market of any food that is not safe, establish a precautionary and

For example, the new EU legislation on contaminants, referred to in Regulation 2023/915/EU, has consolidated and updated the maximum limits in foodstuffs but has not introduced any title or annex related to the matrix of by-products. The same applies to both Regulation 2005/2073/EC on microbiological criteria for foodstuffs and Regulation 2005/396/EC on maximum levels of plant protection products also permitted on foodstuffs.

Overall, therefore, the legislation in question seems to be based on standardized food products typical of traditional categories. This leaves the category of ingredients derived from food upcycling processes, which often have unusual physical and chemical structures, in a state of regulatory uncertainty[329].

The lack of specific parameters for plant by-products causes operators in the industry who sell upcycled food to rely on private guarantee schemes (such as

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one-directional logic focused on *prevention, control, and withdrawal*. Likewise, Articles 17–19 impose sequential responsibilities on food business operators and introduce a traceability requirement intended to facilitate the *recall and removal* of unsafe products, not their re-processing or valorisation. This approach is reinforced by Recitals 9, 11, and 28, which describe food safety governance as a process encompassing all stages of production, processing and distribution a linear chain that terminates at the consumer rather than looping back into production systems. The Regulation contains no explicit reference to by-products, residual streams, or resource recovery within the food chain. Its traceability model, while comprehensive, is oriented toward risk management and market transparency, not toward the circular re-integration of safe materials. Consequently, the General Food Law functions as a closed system of compliance: it prevents unsafe foods from entering or remaining in the market but does not provide a regulatory pathway for reintroducing or upgrading materials of plant origin once they leave the conventional production flow. This structural design substantiates the view that the legal framework governing EU food law remains essentially linear, creating a regulatory gap between existing legislation and industrial practices that now aim to operate within a circular and resource-efficient paradigm.

[329] A.N. SWARAJ, J.A. MOSESB, L. MANICKAM, *Sustainable food upcycling: perspectives on manufacTorinog challenges and certification requirements for large-scale commercialization*, in *Sustainable Food Technologies,* 3, 2025, pp. 648 ff. https://doi.org/10.1039/D4FB00254G

BRCGS, FSSC 22000, IFS, etc.), leading to disparities related to the financial capacity of individual companies to implement them.

The issue is worsened by the absence of a harmonised framework for food upcycling within the European Union, and there is no official certification dedicated to it.

Although this example is related to the private sector and not the institutional one, a reference model for a certification system[330] at the European level could be the Upcycled Certified® developed in the United States. This is the first voluntary certification of its kind globally, aimed at establishing common standards for the identification and labelling of products made using food upcycling techniques, focusing on verifiable criteria such as supply chain traceability and the quantification of reused raw materials.

a) The Notion of "Food" in the Age of Food Upcycling: Towards a Circular Concept

Although Article 2 of Regulation 2002/178/EC, which reflects the definition in the international *Codex Alimentarius*[331], provides a broad and potentially

[330] See, § 2.7.3

[331] The Codex Alimentarius is a comprehensive collection of internationally recognized standards, guidelines, and codes of practice adopted by the Codex Alimentarius Commission (CAC), a body jointly established in 1963 by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Its overarching objective is to protect consumer health, ensure fair practices in the food trade, and promote coordination of all food standards work undertaken by international governmental and non-governmental organizations. The Codex Alimentarius provides the scientific and regulatory foundation for much of today's global and regional food law, including the European Union's General Food Law (Regulation (EC) No 178/2002). It defines principles of food hygiene, safety, quality, and labeling, covering every stage of the food chain (from primary production to processing, packaging, distribution, and retail. Importantly, the Codex emphasizes the risk analysis approach, which includes risk assessment, management, and communication) a methodology later adopted by the EU and other jurisdictions to structure food safety governance.

comprehensive definition of food, regulatory actions and application practices still rely on a linear approach. Food is defined as «any substance or product, whether processed, partially processed, or unprocessed, intended to be, or reasonably expected to be, ingested by humans».

This is a distinctive product that, according to doctrine, can be transformed and appropriated by its consumer[332] . The legal framework governing semantics continues to grapple with legitimizing the use of by-products in food, as legislation classifies them as ontologically different from food itself. This asymmetry, however, impedes the development of proactive and adaptable legal tools for food circularity.

This requires a semantic-legal reinterpretation of the definition of food, where regenerated matter can also be seen as a source of nutrition. From this perspective, and considering the interconnectedness of environmental and food law, the aforementioned principle of circularity, which is currently being developed in doctrine, could serve as a new regulatory criterion in the food sector, just as the principles of prevention and precaution have already done.

Although the Codex standards are not legally binding, they carry significant normative authority and are explicitly referenced in the World Trade Organization's Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). As such, Codex texts often serve as the benchmark for resolving international trade disputes involving food safety. In recent years, the Codex has expanded its scope to include emerging issues such as food fraud, contaminants, allergens, sustainability, and the use of novel ingredients and technologies. Through this evolving framework, it supports a global convergence of food safety practices, ensuring that scientific evidence and consumer protection remain at the core of modern food regulation and international trade. Among scholars, see D. BEVILACQUA, *The Codex Alimentarius Commission and its Influence on European and National Food Policy,* in *European Food and Feed Law Review,* 1, 2006, pp. 3 ff; K. PRUCHNIEWICZ, T. SROGOSZ, *The Codex Alimentarius Standards Decision-making Some Critical Remarks on an Ongoing Discussion*, *ivi,* 6, 2020, pp. 571 ff; B. VAN DER MEULEN, *Impact of the Codex Alimentarius, ivi,* 1, 2019, pp. 29 ff.

[332] See, F. ALBISINNI, *Strumentario di diritto alimentare europeo (European Food Law Toolkit),* Milanofiori Assago, 2015, pp. 11 ff.

Reinterpreting the concept of food within the framework of circularity could pave the way for complete regulatory acceptance of food upcycling processes without sacrificing food safety. This way, production residues could be biologically integrated into the food chain, enabling a clear and systemic application of the previously mentioned food hierarchy.

3.3.2 Novel Foods as an Imperfect Channel for the Up-Cycling of Plant-Based By-Products

After establishing the importance of redefining food within a circular framework and identifying regulatory gaps in food upcycling—such as the reliance of food businesses on private guarantee schemes—it is essential to examine a specific legal instrument that could serve as a pathway for incorporating plant-based by-products into human nutrition. This instrument is Regulation 2015/2283/EU[333] on novel foods[334].

[333] Replacing Regulation 1997/258/EC.

[334] For a general oveview on this topic, see S. RIZZIOLI, *Novel Foods,* in L. COSTATO, F. ALBISINNI (eds.), *European Food Law,* CEDAM, Padova, 2012*,* pp. 393 ff.; C.BALLKE, *The New Novel Food Regulation –Reform 2.0*, in *European Food and Feed Law Review*, 9, 2014, pp. 285 ff.; A. VOLPATO, *La riforma del regolamento sui Novel Food: alla ricerca di un impossibile equilibrio?,* in *Rivista di Diritto Alimentare,* IX (4), 2015, pp. 26 ff.; D.PISANELLO, G.CARUSO (eds.), *Novel Foods in the European Union*, Cham, Springer, 2018; G. FORMICI*, L'evoluzione della disciplina normativa in materia di Novel Food: una sfida sul tavolo del legislatore europeo,* in *Diritto pubblico europeo Rassegna online*, 1, 2018, pp. 1 ff.. L. SCAFFARDI, *Novel Food, un futuro ancora da definire*, in *BioLaw Journal –Rivista di BioDiritto*, 2, 2020, pp. 43 ff; B. LA PORTA, *Il Regolamento europeo in materia di novel food: riflessioni sugli "alimenti tradizionali dei Paesi terzi",* in *Cultura e diritti*, 1, 2020, pp. 59 ff.; V. PAGANIZZA, *I nuovi alimenti ("Novel foods"),* in P. BORGHI, I. CANFORA, A. DI LAURO, L. RUSSO (eds.), *Trattato di diritto alimentare italiano e dell'Unione europea,* Giuffré, Milano, 2021, pp. 560 ff.; L. SCAFFARDI, G. FORMICI, *Novel Foods and Edible Insects in the European Union. An Interdisciplinary Analysis,* Springer*,* Cham, 2022; M. GRUBE, K. PASCH, S. TÖPFL, *The Food Law Assessment of Novel Foods by Process,* in *European Food and Feed Law*

The purpose of this regulation[335] is to establish a pathway for access to foods other than traditional foods produced through methods or sources not commonly used before May 1997. Its goal is to promote technological innovation in the food industry, minimize environmental impacts of production, enhance food safety, and deliver nutritional and economic advantages to consumers.

Currently, the regulation on novel foods is one of the most advanced legal tools for including products derived from processes that valorize plant by-products in human diets.

Article 3(2)(a) of the regulation defines «novel» as any food that has not been consumed significantly in the European Union before May 15, 1997, and that falls into one of the categories listed at[336]. Among these, we highlight the category

Review, 18, 2023, pp. 166 ff.*;* H.SCHEBESTA, K.PURNHAGEN, *Pre-market authorization of novel products: Novel Food Regulation*, in H.SCHEBESTA, K.PURNHAGEN, *EU Food Law*, Oxford, 2024.

[335] Recital 29.

[336] Under the framework of Regulation 2015/2283/EU on Novel Foods, together with Commission Implementing Regulation 2017/2469/EU and the most recent EFSA Guidance on the preparation and presentation of Novel Food applications, the technical dossier accompanying a Novel Food submission must provide a complete and coherent set of information ensuring a full safety assessment of the food under the proposed conditions of use. In line with these requirements, each technical data sheet should contain comprehensive details covering several core aspects. First, the identity of the Novel Food must be clearly established. This includes its name, definition, and source (botanical, animal, microbial, or synthetic), the part or fraction of the source used, and any specific strains, varieties, or production organisms involved. Distinguishing characteristics such as compositional or structural features that differentiate it from existing foods must also be specified. The dossier should then present the specifications and compositional data, detailing the qualitative and quantitative composition, typical analytical values, and permissible ranges for key constituents. Information on impurities, contaminants, and microbiological quality must be provided, together with validated analytical methods and batch-to-batch data demonstrating the reproducibility and consistency of the product. The production process must be described step by step, usually accompanied by a flow diagram illustrating the transformation from raw materials to the final product. This description should include critical processing parameters such as temperature, pH, time, and pressure, as well as purification or extraction steps, enzyme treatments, or fermentation

that specifically includes foods made from or isolated from plant materials, representing a potential avenue for valorizing plant-based by-products. Their inclusion depends on the level of technological innovation in the processing method they undergo and whether they were not substantially consumed in the Union before

processes. The description should also identify control measures, HACCP points, and any use of nanomaterials or novel technologies, providing evidence of safety and traceability throughout the process. The stability of the Novel Food must be documented through appropriate testing, including both real-time and accelerated studies under different storage conditions. These tests should demonstrate that the product maintains its composition, safety, and nutritional properties throughout its intended shelf-life and that potential degradation products do not raise safety concerns.The dossier must specify the proposed uses and use levels, identifying the categories of foods in which the Novel Food will be incorporated, the maximum inclusion levels per 100 g or 100 ml of product, and the intended target population. If necessary, it must also include any conditions of use or labelling requirements to ensure safe consumption.The nutritional information should assess the energy and nutrient contribution of the Novel Food, its bioavailability, and whether its consumption may be nutritionally disadvantageous for the intended population. This analysis ensures compliance with Article 7 of Regulation 2015/2283/EU, which prohibits the authorisation of foods that could be nutritionally unbalanced or misleading for consumers. A thorough toxicological evaluation must also be provided, typically following a tiered approach that begins with in vitro studies (e.g. genotoxicity) and progresses to in vivo studies only when necessary. Where applicable, history of safe use, human data, and information on allergenicity should be presented. The assessment must confirm that the Novel Food does not pose risks to human health under the proposed conditions of use. The estimated exposure of consumers forms a crucial part of the risk assessment. It involves calculating likely intake levels of the Novel Food or its components across different population groups using dietary data, including mean and high-percentile consumption scenarios. This allows comparison between the estimated exposure and toxicological reference points, ensuring an adequate margin of safety. Finally, the technical data sheet must integrate all these elements in a comprehensive risk characterisation, summarising the hazard identification, exposure estimates, uncertainties, and overall safety conclusion. This structured and evidence-based approach reflects the principles established by EU food law and EFSA scientific guidance, ensuring that each Novel Food placed on the Union market is demonstrably safe, nutritionally appropriate, and properly controlled throughout its production and consumption chain.

15 May 1997. This indicates that traditional by-products can qualify as novel foods if they are processed through innovative extraction, fermentation, or enzymatic methods that produce fractions or compounds not previously used for food purposes. An example of this is free fatty acids obtained from grape seed oil.

The inclusion of a product in the novel foods category is subject to a complex centralized authorization process at the European level (though simplified compared to its previous version), for which an application must be submitted to the European Commission, along with a complete technical and scientific dossier. The European Food Safety Authority (EFSA) will issue a scientific opinion on the safety of the product within nine months. The European Commission's authorisation to place the novel food on the market depends on this opinion's outcome. If the product is approved, it will be included in the official EU list, which will describe its conditions of use, quantitative limits, labelling requirements, and post-marketing monitoring obligations.

Despite its intrinsic and undoubted consistency in terms of food safety, the adopted system takes a case-by-case approach, which is objectively insufficient to cover food upcycling practices comprehensively.

The technical-scientific dossier required by EFSA involves costly analyses, such as toxicological tests and risk exposure assessments, which SMEs may not be able to afford.

From a food safety perspective, it should also be noted that novel foods fall within the scope of the General Food Law and related regulations. As previously mentioned, these regulatory instruments, which were originally designed for standard foods, do not include specific annexes or thresholds for ingredients derived from the valorisation of plant by-products.

Consequently, safety assessments are carried out using comparative schemes rather than specific parameters.

Although it is an advanced tool in the field of food sustainability, the novel foods instrument does not serve as an effective channel for the widespread dissemination of bioeconomic upcycling practices.

3.3.3 Traceability of Plant-Based By-Product Flows: The Missing Link in Circular Governance

Ensuring food safety for consumers depends, above all, on the traceability of products throughout the supply chain. Therefore, the General Food Law[337] requires food and feed sector operators to maintain traceability of food, feed, and any substance that may enter the food chain at every stage of the process. This requirement is reinforced by Regulation 2017/625/EU[338] on official controls, which establishes a surveillance system characterized by inspections, audits, and monitoring.

An analysis of this regulation reveals critical issues related to a lack of synchronisation between traceability systems and the evolution of circular food economy mechanisms.

Specifically, the need to valorise agro-industrial residues and by-products has generated a new category of secondary material flows which, through specific processes, can be reintroduced into the human and/or animal food chain.

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[337] Art. 18

[338] F. ALBISINNI, *Il Regolamento (UE) 2017/625: controlli ufficiali, ciclo della vita, impresa e globalizzazione*, in *Rivista di Diritto Alimentare*, 1, 2018, pp. 11 ff. See also, A.G. CARAGLI, M. LEGGIO, *Governance e regolazione del settore agroalimentare verso il paradigma One Health*, cit. p. 221: «The first recital of the regulation explicitly states the objective of pursuing a high level of protection for human, animal, and environmental health through measures in the veterinary and phytosanitary sectors aimed at safeguarding human health. This marks the transition from a conception of food safety related to the individual product already placed on the market to a broader one that considers the entire life cycle of the food».

Nevertheless, the traceability requirements for these secondary flows lack EU standardisation, which leads to uncertainties and fragmentation between different national administrative practices.

In this context, it should be emphasized that renewing European governance of secondary flow traceability could address the urgent needs of food law, environmental law, and industrial policies.

Even through soft law instruments alone, the European Commission and the European Food Safety Authority (EFSA) could develop technical guidelines to clarify traceability standards for these secondary flows.

These could specify a series of critical control points (CCPs) for managing agri-food residues intended for reuse, such as suitable temperatures for stabilising materials, and microbiological, chemical and physical stability indicators.

This example illustrates the intertwining of the needs of ecological and digital transitions. Indeed, emerging digital technologies can significantly improve food data management, in line with the European Digital Strategy.

Tools such as food blockchain systems, Internet of Things (IoT) sensors, artificial intelligence-based predictive analytics, and digital twin technologies help ensure supply chain transparency and anticipate potentially risky scenarios for consumers.

3.3.4 Reusing Plant-Based By-Products within the Technical Flow: The Case of Food Packaging.

a) General Overview of the Food Packaging Sector

The legal and operational issues related to the valorisation of plant by-products in the agri-food industry affect both the biological and technical paths. In fact, these issues are primarily linked to the potential of plant-based by-products in the field of biomaterials for packaging.

Shifting the legal focus to the packaging sector is consistent with the above approach, as it highlights the fact that the food industry is the sector that most urgently requires circular packaging solutions.[339].

Considering its impressive economic turnover of over €370 billion across Europe, the packaging sector is a key area for advancing circular industrial transformation.

The growing amount of packaging waste in the European Union, largely generated by the food sector, necessitates greater regulatory harmonisation among all Member States. On average, each European citizen throws away approximately half a kilogram of packaging per day, and in 95% of cases, the packaging loses its value after its first use[340]. Recently, the European Commission underpinned that many Member States are failing to meet EU recycling targets because of inadequate and ineffective recycling infrastructure and processes[341].

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[339] For a general overview, let me refer to A. DEPIETRI, *Tra economia circolare e sostenibilità alimentare. Le sfide di armonizzazione del mercato europeo del packaging,* in *Federalismi*, 23, 2024, pp. 97 ff.

[340] The data reported are those from the Eurostat Report 2023, *Packaging waste statistics,* https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=Packaging_waste_statistics#Waste_generation_by_packaging_material the latest upgrade of the report refers to the year 2021.

[341] On this point, see Communication COM (2023) 304 final, which identifies the Member States that are at risk of not achieving the 2025 target for the preparation for reuse and recycling of

In this way, the challenge of circular packaging presents itself as a clear and universal issue.

b) Rethinking plastic packaging between circular economy goals and food safety requirements

The plastic packaging sector is particularly complex, as the versatile mechanical properties and low cost of fossil-based plastic polymers make them difficult to replace.

The key technical issue to be tackled, and the foundation for developing public policy strategies and interventions, is to identify alternatives to oil for producing new plastic and to boost the use of recycled plastic, particularly in a closed-loop system.

Therefore, there is a need to create a 'post-use plastic' economy that can overcome the limitations of mechanical recycling and promote innovative alternatives, such as chemical recycling or design for reuse.

Another problematic issue is the dispersion of plastic in the environment, which causes damage to biodiversity and endangers the safety of the food chain (it

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municipal waste, the 2025 target for the recycling of packaging waste and the 2035 target for the reduction of waste sent to landfill. In particular, page 4 of the Communication states: Overall, according to the assessment carried out by the European Environment Agency, the majority of Member States are at risk of not achieving the 2025 targets for preparing for reuse and recycling of municipal waste. More specifically, with regard to the targets of preparing for reuse and recycling 55% of municipal waste and recycling 65% of all packaging waste by 2025: 9 Member States are on track to achieve both targets: Austria, Belgium, the Czech Republic, Denmark, Germany, Italy, Luxembourg, the Netherlands and Slovenia; Eight Member States are at risk of missing only the target for municipal waste, but not the target for recycling all packaging waste: Estonia, Finland, France, Ireland, Latvia, Portugal, Spain and Sweden; 10 Member States are at risk of missing both the municipal waste target and the target for all packaging waste for 2025: Bulgaria, Cyprus, Croatia, Greece, Lithuania, Malta, Poland, Romania, Slovakia and Hungary.

is well known that the ingestion of microplastics by marine animals can compromise the food chain).

Clearly, these challenges have long been part of the system, given the need to harmonise policies in this sector across different EU Member States. This is evidenced by the fact that the plastics sector, in addition to being the subject of an *ad hoc* strategy in 2018[342] , represents an independent policy area of *the* 2020 *Circular Economy Action Plan*. The specific sectoral *policies* adopted by the European Union concern microplastics[343] , *the import- export* of plastic waste[344] ,

[342] This refers to *the European Strategy for Plastics in a Circular Economy,* as set out in the European Commission Communication COM (2018) 28 final. As can be seen from the introduction, this strategy aims to «rethink and improve the functioning of such a complex value chain requires efforts and greater cooperation from all key stakeholders, from plastics producers to recycling operators, from retailers to consumers. It also requires innovative solutions and a shared vision to steer investment in the right direction. The plastics industry is very important to the European economy; increasing its sustainability can create new opportunities for innovation, competitiveness, and employment, in line with the objectives pursued by the EU's new industrial policy strategy».

[343] Among the initiatives adopted at EU level to combat microplastic pollution, we would like to highlight the recent European Commission Communication on *the Proposal for a Regulation of the European Parliament and of the Council on the prevention of plastic pellet dispersion to reduce microplastic pollution,* COM (2023) 645 final. As highlighted in the introduction, this proposal aims «to reduce the dispersion of pellets in the environment and would lead to a decrease of between 54 % and 74 % compared to the baseline scenario, equivalent to a 6 % reduction in the total amount of unintentional microplastic releases. In line with the Commission's target of a 30% overall reduction in microplastics released into the environment, it will contribute to preserving ecosystems and biodiversity, reducing potential health impacts and promoting local economic activities. It also has the potential to improve information on the extent of pellet dispersal throughout the supply chain. Less burdensome requirements for SMEs will ensure adequate mitigation of potential impacts on their activities».

[344] The specific reference is to Regulation 2024/1157/EU on shipments of waste, which amends Regulations 1257/2013/EU and 2020/1056/EU and repeals Regulation 1013/2006/EC.

the *global agreement on plastics*[345] *, and plastic packaging waste.* The latest European legislation aims to reduce the use of plastic products through two main approaches: phasing out or restricting certain products from being placed on the market, and promoting the adoption of alternative plastics[346].

In this regard, Directive 2015/720/EU[347] , which addresses the unsustainability of *lightweight plastic carrier bags,* has instructed Member States to take all necessary measures to reduce their use[348] .

Furthermore, Directive 2019/904/EU[349] , better known as *the Directive on single-use plastics (SUP),* aims to tackle the problem of dispersing single-use

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[345] In 2022, the United Nations Environment Assembly, meeting in Nairobi, began negotiations on a legally binding global agreement to combat plastic pollution. EU diplomacy played a key role in securing the support of the worldwide community gathered in Nairobi for this agreement, which aims to reduce and eventually eliminate plastic pollution in all environments. Hopefully, these negotiations should be concluded in 2025, culminating in the conclusion of the global agreement, which should address plastic pollution throughout the entire life cycle of plastics, to minimise the mismanagement of plastics and prevent them from entering the environment.

[346] R. STUPAZZINI, A. MARTINI, *Il ciclo di vita dei prodotti in plastica nell'era dell'economia circolare,* in *Il Diritto dell'Economia, 3, 2023,* pp. 237 ff.

[347] Amending Directive 94/62/EC on packaging and packaging waste.

[348] With regard to the transposition of this directive into Italian law, see R. STUPAZZINI, A. MARTINI, *Il ciclo di vita dei prodotti in plastica nell'era dell'economia circolare,* in *Il Diritto dell'Economia*, *cit.,* pp. 237 ff. and V. CAVANNA, *Il caso degli "shoppers" di plastica: verso un addio alla plastica?,* in *Rivista Giuridica dell'Ambiente,* 3, 2018, pp. 487 ff.

[349] Among the various contributions in which the directive has been discussed, the following are noteworthy: *Lotta alla plastica ed ecosistemi marini. Il quadro giuridico all'indomani della direttiva UE/2019/904*, in *Przegląd Prawa Rolnego*, 2019, 1, 24, 183 ff.; E. CAPONE, *La direttiva (UE) 2019/904 (Single Use Plastics - SUP o ''Plastic Free'') e la protezione del territorio da parte degli enti locali*, in *Rivista Giuridica dell'Ambiente online*, 2019, pp 5 ff; L. ARISTEI, *Verso una società plastic free. La direttiva 2019/904/UE e la sua attuazione a livello nazionale e regionale*, in *Federalismi*, 25, 2020, pp. 1 ff.; U. BARELLI, *La strategia e le norme dell'Unione Europea contro la dispersione della plastica nell'ambiente e la loro attuazione in Italia, nelle Regioni e nei Comuni,* in *Rivista Giuridica dell'Ambiente online*, 10, February 2020; L. ARISTEI, *A plastic word. Ups and*

plastic items, starting with oxo-degradable plastics[350] and fishing gear containing plastic. This directive seeks to prevent certain single-use plastic products (most of which belong to the *food* sector*)* from being placed on the market[351] and to reduce the consumption of those for which there are no alternatives (for which strict marking requirements are established to guide consumers towards correct disposal methods)[352].

Aligned with the legislation above, the new «Packaging and Packaging Waste Regulation» (hereinafter PPWR) also aims to cut packaging waste[353] . Its

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downs in the national application of Directive 2019/904/EU, in *Italian Journal of Public Law*, 2, 2022, pp. 490 ff.

[350] These are plastics containing additives which, through oxidation, cause the plastic to fragment into micro-fragments or undergo chemical decomposition.

[351] Namely, cutlery (forks, knives, spoons and chopsticks); plates; straws and cotton buds (except those used with active implantable medical devices or other medical devices); beverage stirrers; balloon sticks, except for balloons for industrial or other professional uses and applications that are not distributed to consumers, and related mechanisms; expanded polystyrene food containers (i.e. boxes with or without lids) for immediate consumption without further preparation, generally consumed directly from the container or ready for immediate consumption without further preparation; products made from oxo-degradable plastic; expanded polystyrene beverage containers and related caps and lids; and expanded polystyrene beverage cups and related caps and lids.

[352] On this point, see the Commission Communication *Proposal for a Regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904 and repealing Directive 94/62/EC,* COM, 2022, 677 final.

[353] The PPWR regulation has several main operational objectives, which are summarised below. First and foremost, the reduction of packaging through a 5% reduction in the total volume of packaging by 2030, 10% by 2035 and 15% by 2040, mainly through the elimination of so-called unnecessary packaging, the definition of a maximum empty space limit of 50% for multiple packaging, and the promotion of eco-design. unnecessary packaging, setting a maximum empty space limit of 50% for multiple packaging, and promoting eco-design. Secondly. The ban on single-use plastics in all cases where they are not irreplaceable by 2030 (effectively extending the time frame originally envisaged by the SUP), ultra-light plastic bags and the promotion of bioplastics

objectives include an overall reduction in packaging and a ban on specific single-use plastics by 1 January 2030. This applies to packaging for fresh produce, as well as food and beverages served in bars and restaurants. It also includes single-portion items, such as condiments and sugar, and small single-use packaging used in hotels.

Recognising the need to reduce the use of these types of plastics, the European Union is promoting biobased, biodegradable and compostable plastics as an alternative to traditional packaging. As the aforementioned regulation stipulates the mandatory use of biodegradable and compostable plastics for certain types of packaging, the Commission has already drawn up an initial strategic plan for the use of these innovative polymers for 2022[354].

(with a particular focus on biodegradable and possibly compostable ones). Third, the promotion of conditions for reuse, recyclability and recycling through, for example, the definition of the minimum content of recycled material in plastic packaging, the setting of minimum targets in terms of the weight of recycled packaging, and the definition of separate collection and reuse obligations for certain packaging, such as that for certain alcoholic and non-alcoholic beverages, multiple packaging and packaging for sale and transport.

[354] The reference is to the Commission Communication, *EU Strategic Framework on Bio-based, Biodegradable and Compostable Plastics,* COM, 2022, 682 final.

Besides clarifying the definitions of bioplastics[355] , compostable plastics[356] and biodegradable plastics[357] , the Communication is based on a highly significant fact: globally, the latter represent only 1% of total plastic production capacity, with a volume of over two million tonnes per year.

The limited market share of these alternative plastics indicates a need for more public policies to boost production in the sector, using various legal tools. The upcoming PPWR regulation is already a key command-and-control measure on this issue. However, it should be complemented by soft law measures to help the plastic packaging industry offset the costs of switching to new production models and to

[355] *Ibid.,* «The term "bio-based" in relation to plastics refers to the raw materials used in their production. While conventional plastics are produced from fossil resources (oil and natural gas), bio-based plastics are obtained from biomass. Currently, biomass comes mainly from plants grown specifically to be used as raw materials to replace fossil resources, such as sugar cane, cereal crops, oil crops or non-food sources such as wood. Other sources include organic waste and by-products, such as used cooking oil, bagasse and tall oil. Plastics can be produced entirely or partially from bio-based raw materials. As illustrated in the figure below, bio-based plastics can be biodegradable and non-biodegradable».

[356] *Ibidem,* «While conventional plastics do not decompose at the end of their life cycle, those designated as "biodegradable" are designed to decompose at the end of their life cycle by converting all their organic constituents (polymers and organic additives) mainly into carbon dioxide and water, new microbial biomass, mineral salts and, in the absence of oxygen, methane. For this to occur, in addition to the characteristics of the plastic material, suitable conditions in the receiving environment and sufficient time are required. For this reason, the biodegradability of plastics must be considered not only in terms of material properties, but above all in terms of 'system properties', in which factors related to materials and the environment are equally important. As illustrated below, plastics designed to biodegrade can be either bio-based or fossil-based».

[357] *Ibid.,* « "Compostable plastics", a subset of biodegradable plastics, are designed to biodegrade under controlled conditions, usually through industrial composting in special composting or anaerobic digestion plants. Biodegradable plastic waste intended for industrial composting must first be collected. There is a European standard for industrially compostable packaging, but not for home composting, as the conditions for the latter can vary considerably».

limit the final prices of products in these packages. Legal and political considerations are further complicated by technical challenges, such as the practicality and operational feasibility of converting industrial production to biopolymer-based packaging.

Furthermore, the use of plastic packaging for food products raises specific food safety issues linked to European legislation on recycled plastic in contact with food. This is governed by Regulation 2022/1616/EU, which will be binding on Member States from 10 July 2023.

This regulation primarily focuses on three key aspects: the sale of plastic materials and products made using suitable waste plastic recycling technologies intended for use with food; the development and operation of recycling technologies, processes, and facilities for producing recycled plastic; and the use of plastic materials and products intended for use with food that have been or are to be recycled.

Additionally, Regulation 2023/1442/EU ensures a high level of safety for consumers' and workers' health when producing packaging intended to come into contact with food. It updates the list of substances authorised for the manufacture of FCMs (Food Contact Materials) and modifies the authorisation system for their use[358].

[358] Specifically, this regulation – which amends Technical Annex I to Annex I of Regulation 2011/10/EU on FCM – stems from the need to amend the legal framework in line with the scientific opinions published by EFSA.

c) From Plant-Based By-Products to Bioplastics: New Frontiers for Sustainable Food Packaging

The valorisation of plant-based by-products in the bioplastics sector is hindered by specific regulatory issues that prevent the widespread adoption of circular biopolymers in industry.

First and foremost, the problem is linked to the definitional difficulties outlined in European legislation on by-products, which were discussed at length in the previous chapter. The conversion of plant by-products into biopolymers involves complex physical and chemical processes, making it unclear whether this constitutes normal industrial practice as defined in Article 5 of Directive 2008/98/EC.

Therefore, it is unclear whether the extraction, fermentation or polymerisation processes significantly modify the production residue to the extent that the "End of Waste" category applies.

This definitional uncertainty is exacerbated by a lack of coordination between the FCMs and PPWR regulations: while the FCMs regulations specify migration limits, substance purity requirements and safety standards for food contact, the PPWR focuses on harmonising the internal market and promoting new bio-based materials.

In other words, while the PPWR emphasises advancing bio-packaging supply chains, the FCMs regulations currently seem to favour food safety safeguards based on more linear and conservative approaches, rather than being aligned with bio-circularity.

Still, in the context of bio-packaging, it is also important to highlight potential critical issues inherent in extended producer responsibility (EPR) schemes, as outlined by the European Directive on waste management and referred to by the PPWR itself as one of the most effective economic tools for promoting circularity in the packaging sector.

In full compliance with the “polluter pays' principle", EPR[359] allocates financial and organisational responsibility for the management of packaging at the end of its life to producers. This involves setting differentiated contributions that are inversely proportional to the product's lifespan on the market.

In practice, however, the calculation criteria for many EPR schemes are still calibrated to conventional materials without considering the specific characteristics of bioplastics derived from plant by-products, for example.

Promoting plant-based by-products could therefore significantly boost the bioplastics market, provided these innovative materials are fully integrated into the regulations of various key sectors.

3.3.5 Functional Materials Derived from Plant-Based By-Products: A Hybrid Case between Technical and Biological Flows

The discussion can be broadened by focusing on functional materials[360]. These materials bridge the gap between the technical and biological aspects of the circular economy. They perform a containment function for packaging and act as protective barriers to preserve the product. They also interact directly with food through active or edible components.

This dual functionality blurs the boundaries between materials and foodstuffs, raising legal issues concerning safety, traceability, and regulatory classification. It is important to note in the present case that these materials are often produced using by-products of plant origin.

Examples include edible films and coatings made from starches derived from potato skins and cereals, or from proteins obtained from legume processing by-products. Biodegradable films obtained from oil industry by-products and

[359] See notes nn. 163-164

[360] For an in-depth analysis see S. BANERJEE, A.K. TYAGI, *Functional Materials Preparation, Processing and Applications,* Elsevier Science, Amsterdam, 2012 https://doi.org/10.1016/C2010-0-65659-8 .

bioactive coatings designed to extend food's shelf life are often made from citrus or tomato waste.

At a regulatory level, Regulation 2009/450/EC introduces the concept of «active and intelligent materials and articles intended to come into contact with food». The Regulation distinguishes between active materials, which are designed to extend the shelf life of food and preserve its hygienic and sensory qualities, and intelligent materials, which are intended to monitor the state of the food or packaging environment.

Despite the partially successful attempt to implement integrated, systemic solutions that link food safety, environmental sustainability, and technological innovation, the regulation is based on the traditional distinction between food and materials.

This creates a grey area that encompasses all those technological innovations which, in addition to performing the typical functions of functional materials, are also edible (e.g. coatings and food films derived from plant by-products). Due to this regulatory fragmentation, food business operators are forced to manage the overall regulation on food contact materials (FCMs), novel foods and food additives without clear guidelines.

Given these considerations, it is also important to modify and align the regulatory framework to create a European governance system for the bioactive materials industry. The industry is currently navigating uncertain waters and must rely on costly private services to avoid potential criminal liability.

3.4. The Role of Public Authorities Between Hard and Soft Governance: Procurement, Nudging and Moral Suasion in Promoting Plant-Based By-Products

The analysis of the framework's complexity aimed to identify key issues and systemic questions for improving the governance of the food circular economy, where plant by-products can be utilized according to their natural potential. Therefore, the approach has been top-down: systemic gaps have been identified in a legal framework still rooted in linear thinking patterns. The results are lower circularity performance than theoretically attainable, restrictions on the interoperability of the internal market category of by-products, and uncertainties for economic operators in the sector.

The high technical and bureaucratic costs that hinder the valorisation of by-products, especially for SMEs, discourage the widespread adoption of mature industrial symbiosis models.

As highlighted in the previous chapter, however, the EU context provides various incentives for transforming production systems into a circular model. Since tools like subsidies, tax relief, and the promotion of specific certifications can clearly serve as significant drivers for a circular approach to food systems, it is appropriate to focus the analysis on public procurement as a key instrument.

As already mentioned, public demand is actually a key factor in guiding and financially supporting sustainable choices in the world of production.

Within the well-established framework of Green Public Procurement, there is a unique institution known as Food Public Procurement[361], which is the primary

[361] For an in-depth analysis on this topic, see FAO, ALLIANCE OF BIOVERSITY INTERNATIONAL AND CIAT AND EDITORA DA UFRGS, *Public food procurement for sustainable food systems and healthy diets,* Vol. 1. Roma, 2021. M. STEIN, M. MARIANI, R. CARANTA, Y. POLYCHRONAKIS (eds.), *Sustainable Food Procurement: Legal, Social and Organisational Challenges,* New York, 2024.

channel through which public administrations across Europe can intervene as direct market players to guide production and consumption choices along the agri-food supply chain[362] .

The issue concerns public food procurement policies, with particular reference to best practices in the design of tenders through collaboration between contracting authorities.[363]. Regarding this issue, certain shared experiences have proven particularly effective in promoting public food procurement models that balance environmental sustainability, nutritional quality, social inclusion, and public spending efficiency[364].

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[362] See, L.FJ. SWENSSONA, D. HUNTERB, S. SCHNEIDERC, F. TARTANACA, *Public food procurement as a game changer for food system transformation,* in *The Lancet Planetary Health,* 5*(*8), e495-e496. Please, let me refer to A. DEPIETRI, *The Strategic Role of Public Food Procurement in the Just Food Transition,* in *Biolaw Journal-Rivista di Biodiritto,* 3, 2025, pp. 115 ff. https://doi.org/10.15168/2284-4503-3695

[363] The topic of call for tenders' design is of great interest, as it constitutes the main step towards the effective pursuit of the results sought by procurement policies. For some general theories on the subject, see, for example, A. P. KING. *Enhancing the effectiveness of design and build tendering*. Diss. Sheffield Hallam University (United Kingdom), 2008; R. KOZIK, *The process of the tender evaluation in public procurement for implementation of design documentation*, *IOP Conference Series: Earth and Environmental Science*. Vol. 222. 1, 2019.

[364] In this sense, the development of operational platforms that foster collaboration and knowledge sharing among public administrations and stakeholders proves particularly valuable. An example is the European Procurement Forum (EUPF) — a network that brings together public authorities, procurement professionals, experts, and representatives from various European countries. The Forum facilitates the exchange of knowledge, experiences, and best practices in the field of sustainable public procurement, promoting continuous dialogue through workshops, events, online platforms, and joint publications. By encouraging innovative and cooperative approaches, the EUPF contributes to enhancing the effectiveness of procurement processes and ensuring their alignment with the objectives of key European sustainability frameworks, such as the European Green Deal and the Farm to Fork Strategy https://eupf.org/. In parallel, the Buy Better Food Campaign represents another significant European initiative aimed at supporting public administrations in improving the quality and sustainability of food procurement. Through this

Several Member States[365] have developed collaborative best practices[366], which are based on replicable models for sustainable public food procurement. This shows how effective cooperation can be between public administrations, local stakeholders, and industry.

The implementation of these best practices often involves the creation of purchasing centres that promote the exchange of expertise, the joint drafting of specifications, the definition of innovative criteria, and the sharing of strategies for monitoring and evaluating impacts. In this way, collaboration among entities allows for overcoming the structural difficulties faced by individual administrations and

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campaign, local authorities, schools, hospitals, and other public facilities can access practical resources, examples of sustainable procurement practices, training tools, and information materials designed to integrate environmental, social, and nutritional criteria into their purchasing procedures. Its overarching goal is to promote procurement models that prioritise local, organic, seasonal, and environmentally friendly products, thereby contributing to the transformation of public food systems into healthier, fairer, and more sustainable models https://buybetterfood.eu/.

[365]These initiatives illustrate how sustainable public procurement can act as a concrete driver for implementing the objectives of the European Green Deal and the Farm to Fork Strategy, fostering the transition towards more sustainable and inclusive food systems. Projects such as the *Green Deal Cantines Durables* in Wallonia, *The Kitchen of Tomorrow* in Denmark, and the *Milan Food Policy* in Italy demonstrate the potential of local governance models to integrate environmental, social, and economic dimensions. By promoting short supply chains, plant-based and organic sourcing, and food waste reduction, these experiences show that public catering services can become laboratories for innovation and social equity, translating European sustainability goals into tangible practices at the local level.

[366] For a contextualization of best practices, in terms of definition and systematization in the field of Administrative Law, see D. ZARING, *Best practices*, in *NYU Law Review,* 81, 2006, pp. 294 ff. See also F. FRACCHIA, P. PANTALONE, *La fisionomia delle linee guida: abbozzo di una traiettoria evolutiva con specifico riferimento al settore dei contratti pubblici,* in *Il Diritto dell'Economia*, 104 (1), 2021, pp.11 ff.

helps to improve the quality of tendering procedures through the sharing of experience and resources.

Such practices can encourage the adoption of more integrated public policies by administrative bodies, and can serve as instruments of technical and legal innovation, representing a cooperative and proactive approach to administration.

Regarding the valorization of plant-based by-products, it would be beneficial to include bonus clauses in calls for tenders for all operators who document industrial symbiosis practices or projects aimed at valorizing by-products through economies of scale. In this way, leveraging public demand could enhance the competitiveness of SMEs and promote the widespread adoption of good circular economy practices within the food sector's production industries.

Furthermore, the Food Procurement tool, focused on food circularity models, can influence producers and consumers. The valorization of by-products in food procurement for public services is connected to non-coercive methods based on moral suasion and/or nudging[367]. The latter can play a crucial role in educating consumers to adopt food upcycling practices and the idea of circular food[368].

[367] Please refer to L. MÉLON, *More than a nudge? Arguments and tools for mandating green public procurement in the EU,* cit.; D. KLINGLER, S. L. SCHOONER, *Promoting Sustainable Public Procurement Through Economic Policy Tools: From Moral Suasion to Nudging, in European Journal of Public Procurement Markets,* 4(4), 2023, pp. 67 ff.

[368] Consumer perception emerges as a key factor in determining the market acceptance of upcycled food products. Research indicates that the success of upcycling within agri-food systems depends not only on technological innovation and supply-chain efficiency, but also on the willingness of consumers to adopt foods derived from by-products. Several elements influence this acceptance, including environmental awareness, trust in information and labelling, familiarity with waste-to-value concepts, and emotional responses such as perceived risk or aversion.On this point, see J. ASCHEMANN-WITZEL, I. DO CARMO STANGHERLIN, *Upcycled by-product use in agri-food systems from a consumer perspective: A review of what we know, and what is missing,* in

While moral suasion involves non-coercive influences like policies, guidelines, and information campaigns by public administrations to guide the food system toward more sustainable and ethical models, nudging[369], on the other hand, uses actual behavioral levers aimed at influencing consumer choices to promote more responsible food decisions[370]. Both tools can be seen as drivers of a just transition[371] in the food system.

Technological Forecasting and Social Change, 168, 2021, pp. 120749 ff. https://doi.org/10.1016/j.techfore.2021.120749

[369] This theory is based on the premise that there is no decision without context, and people often make decisions with according to the findings of behavioral science, people often experience cognitive distortions and errors when making decisions. The theory argues that, through appropriate construction of the context (also known as choice architecture), it is possible to push (encourage, prod) people to make decisions and behave in ways that increase of the context, also known as choice architecture, to enable people to make decisions and behave in ways that increase their own well-being, as well as the well-being of others. C. R. SUNSTEIN, R. THALER, *Nudge. La spinta gentile. La nuova strategia per migliorare le nostre decisioni su denaro, salute, felicità*, Feltrinelli Milano, 2008. For an in-depth legal analysis about nudging in the field of Administrative Law, reference is made to A. ZITO, *La nudge regulation nella teoria giuridica dell'agire amministrativo,* Editoriale Scientifica, Napoli, 2021. See also, L. LEONE, *When Nutrition Policy Meets Behavioural Sciences. Regulating-by-Nudging in the Innovation Union,* in *Rivista di Diritto Alimentare*, 1, 2017, pp. 20 ff.

[370] This topic also intersects with the issue of consumer education, which is considered a key lever for promoting more sustainable and responsible consumption behaviours. See E. SIRSI, *Il diritto all'educazione del consumatore di alimenti,* in *Rivista di Diritto Agrario*, XC, (4), 2011, pp. 496 ff.; A. DI LAURO*, Comunicazione pubblicitaria e informazione nel settore agro-alimentare*, Giuffré, Milano, 2005, ID., *La comunicazione e la disciplina della pubblicità nel settore agroalimentare*, in *Trattato di diritto agrario*, vol. III, Giappichelli, Torino, 547; ID. (ed), *Nutridialogo*, Bologna, 2016; S. BOLOGNINI, *Il consumatore nel mercato agro-alimentare europeo fra scelte di acquisto consapevoli e scelte di acquisto sostenibili*, in Rivista di Diritto Agrario, I, 2019, pp. 615 ff.

[371] About the topic of Just Transition, see R.J. HEFFRON, *Achieving a Just Transition to a Low-Carbon Economy*, Springer, Cham, 2021; J. MORRISON, *The Just Transition A Systems-Thinking Approach To Managing Climate Action,* Springer, Cham, 2024.

3.5 The Role of Consumers in Circular Food Systems: Transparency, Trust, and the Valorisation of Plant-Based By-Products. Some Concluding Reflections

As previously mentioned, consumer choices have a significant influence on industrial, production and governance strategies. This remains an unquestionably relevant role for plant-based and bio-circular agri-food supply chains.

The uptake of circular foods obtained through food upcycling processes and innovative products, as well as biocircular solutions such as bioplastics, depends on consumers accepting new regenerative models. Regarding plant-based food by-products, consumers must evaluate their acceptance of products such as fruit and vegetable waste, oils extracted from secondary seeds, fibres obtained from peels, and natural additives derived from pressing residues.

While the problem is linked to fragmented legislation and extremely high operating costs from an industrial perspective, from the consumer's point of view it is linked to a lack of information and trust in these new substances. Regulation 2011/1196/EU aims to address this issue by providing consumers with food information. However, this information focuses primarily on nutritional and health values, paying insufficient attention to the origin, circulation or regeneration of ingredients.In this context, product labelling is a key tool for encouraging the use of plant-based by-products.

The introduction of food circularity labels would educate consumers about the importance of ingredients from reused or regenerated plant sources.

However, improving the labelling system and ensuring transparent information also requires investment in food literacy. Food literacy encompasses the dissemination of knowledge, skills, and behaviours that enable consumers to understand the environmental, social, and legal value of food.

In the context of food circularity, food education is crucial: it would help to make the idea of food upcycling more widely understood and socially accepted. At

the European level, initiatives such as the EIT Food partnerships[372], promoted by the European Institute of Innovation and Technology, are already addressing these integrated educational challenges. Citizen Engagement and Living Labs programmes involve consumers in co-designing sustainable food solutions and experimenting with transparent labelling models.

Active citizen participation in such design processes makes it possible to translate the principles of circularity into everyday practices of conscious consumption and collective responsibility.

[372] EIT Food builds partnerships across multiple stakeholders to foster a fair, healthy, and sustainable European food system, engaging Community Members, Delivery Partners, and Strategic Partners according to their specific roles within the agri-food innovation landscape. https://www.eitfood.eu/partnerships

Chapter 4: Measuring Circularity through Law: Empirical Tools and Legal Indicators for the Valorisation of Plant-Based By-Products

4.1 From dogma to Reality. The Empirical Shift in European legal science

As the analysis conducted so far has shown, it is no longer possible to attribute law to a self-sufficient and closed system. Through the challenges linked to the complexity of transitions, the very concept of normative rationality makes it increasingly necessary to investigate the horizons and boundaries of the observability, measurability and assessability of the legal world[373] .

These aspects are linked to what is known in legal theory as the empirical turn in legal research. This is a change of direction that replaces the main question of what law is with the question of what law does. From this perspective, Empirical Legal Research complements traditional legal doctrine, placing particular importance on the role of data: among its typical activities, this new line of analysis involves the collection and systematic analysis of data relating to legal phenomena, using various methodologies (which, as in the hard sciences, are verifiable and reproducible)[374] .

This chapter, therefore, aims to offer a brief and practical methodological section on the role of *Empirical Legal Research* tools in the circular economy sector. Its purpose is to identify a possible method suitable for translating the key

[373] In legal scholarship, this aspect is represented by the gap between *law in books* and *law in action.* On this point, reference is made to R. POUND, *Law in books and Law in action,* in American Law Review, 4 (1), 1910, pp. 12 ff.

[374] On the doctrinal debate regarding the desirability of measuring law, see A. SUPIOT, *La gouvernance par les nombres,* Fayard, Paris, 2015; I. PARIENTE-BUTTERLIN, *Le droit, la norme et la réel,* PUF, Paris, 2005.

aspects of the issue of by-products in the agri-food sector (including pnat-based ones) into observable data and to highlight the now clear need for dialogue between regulations, production processes and ecological transitions.

The data that the legal dimension can offer may concern both the legal regulations themselves (such as articles, judgments, administrative acts) and their functioning in society (such as the behaviour of the actors required to apply them, the effects they produce, and the distortions they generate). The law, therefore, becomes a broader field of analysis which, in addition to pure dogmatic reconstruction[375] , takes on the empirical connotations of an observable social phenomenon[376] . This suggests that the complexity of reality should not be

[375] This perspective marks a clear break with the European doctrinal tradition, historically oriented toward the systematisation of law. Since the Middle Ages, the European jurist — from glossator to commentator, and later to codifier — has conceived of their role as one of ordering and interpreting legal sources, seeking the logical coherence of the legal system. Doctrine thus became the paradigmatic form of legal science: an *internal knowledge* aimed at describing law from the standpoint of law itself. This approach remained dominant even after the emergence of the social sciences. The academic division of labour, consolidated between the nineteenth and twentieth centuries, assigned to jurists the monopoly over normative interpretation. At the same time, sociologists and economists were tasked with analysing behaviours and the effects of norms. As a result, law has largely remained impervious to empirical methods. For a general overview of the evolution of empirical legal science, see J. BÉTAILLE, *From Doctrine to Data: Towards an Empirical Turn in European Legal Scholarship,* in *European Journal of Empirical Legal Studies, 1*, 2025https://doi.org/10.62355/ejels.25120

[376] On this point, reference is made to D. GESUALDI-FECTEAU, E. BERNHEIM, *La recherche empirique en droit: méthodes et pratiques,* Édition Themis, Université de Montréal, 2021. The authors offer one of the most comprehensive reflections on the methodological renewal of contemporary legal scholarship. The work highlights the persistent gap between traditional doctrinal approaches—centred on systematisation and interpretation of norms—and the emerging empirical perspective, which studies law as a social practice through observation and data analysis. The authors explore how empirical research can complement normative reasoning by examining how law is implemented, experienced, and transformed within institutions and society. They discuss both qualitative and quantitative methodologies, emphasising research design, data collection, and the

addressed with dichotomous simplifications, but rather with shared observation tools, in which all the knowledge involved can make an effective contribution without renouncing the specificity and ethical function of legal knowledge.

interpretative challenges of translating empirical findings into legal knowledge. The book also underlines the importance of interdisciplinarity, encouraging collaboration between legal scholars and social scientists. Ultimately, it presents empirical legal research as a path toward a more reflexive and evidence-based legal science, capable of connecting doctrinal analysis with the concrete functioning of law in action. Regarding some contributions on Empirical Legal Research, see also M. O. FINKELSTEIN, *Basic Concepts of Probability and Statistics in the Law,* Springer, New York, 2009; F. L. LEEUW, J. J. G. SCHMEETS, *Empirical Legal Research: A Guidance Book for Lawyers, Legislators and Regulators,* Edward Elgar Publishing, Cheltenham, 2016; R. M. LAWLESS, J. K. ROBBENNOLT, T. S. ULEN, *Empirical Methods in Law,* 2nd ed., Wolters Kluwer, New York, 2016; H. ZEISEL, D. KAYE, J. B. WEINSTEIN, *Prove it with Figures: Empirical Methods in Law and Litigation,* Springer, New York, 1997; S. M. CRAFTON, M. F. BRINIG, *Quantitative Methods for Lawyers,* N.C, Carolina Academic Press, Durham, 1994; J. ASHER, D. L. BANKS, FRITZ SCHEUREN (eds.), *Statistical Methods for Human Rights,* Springer, New York, 2008; J. HEINZ (ed), *Analysing Law's Reach: Empirical Research on Law and Society,* Chicago, American Bar Association, 2008; H. M. KRITZER, *Advanced Introduction to Empirical Legal Research,* Edward Elgar Publishing, Northampton, 2021; M. McConville, W.H. CHUI (eds.), *Research Methods for Law,* 2nd ed., Edinburgh University Press, Edinburgh, 2007.

Through legal empiricism, therefore, the epistemological isolation of law is broken, maintaining its object but renewing its methods of investigation. According to contemporary empirical doctrine, these aspects anticipate an evolution in legal research methods, which will necessarily become hybrid[377] .

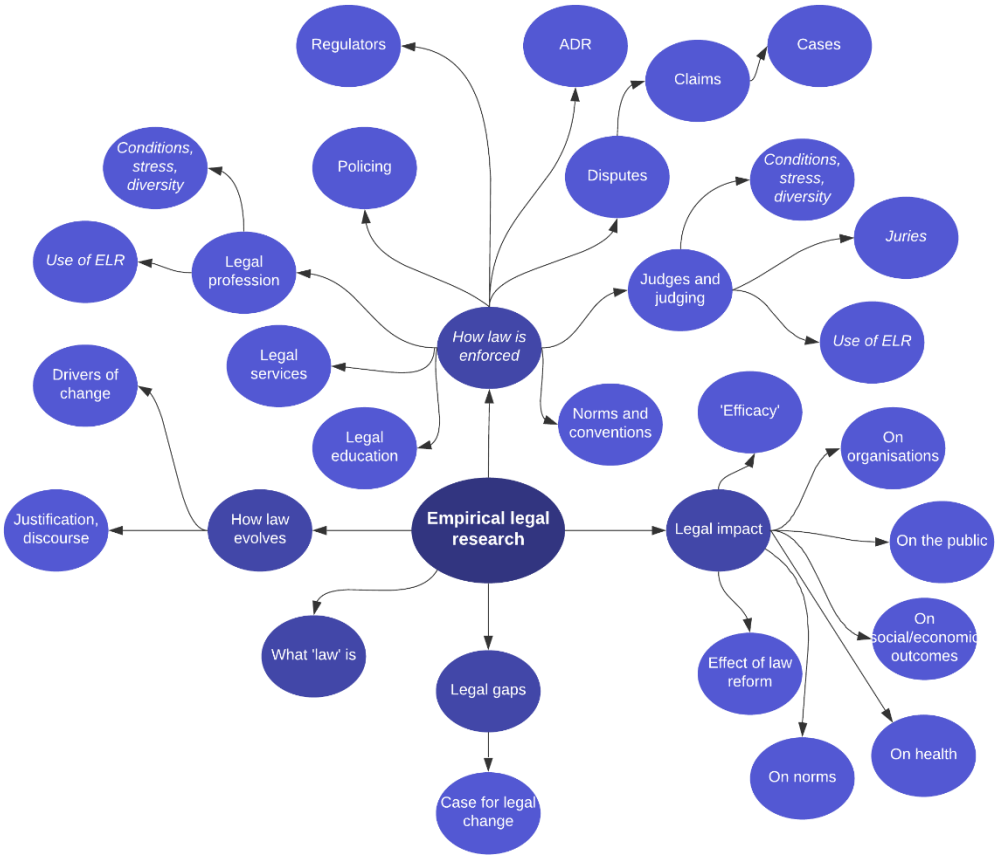

Figure 2 Map of the fields that can be approached through an empirical perspective on law

[377] See, A. DYEVRE, W. WIJTVLIET, N. LAMPACH, *The future of European legal scholarship: Empirical Jurisprudence,* in *Maastricht Journal of European and Comparative Law,* 2019, 26(3), pp. 348 ff. DOI: 10.1177/1023263X19840263

As can be seen from the image above[378] , Empirical Legal Research is divided into areas concerning the application of law (how law is enforced), its effects (legal impact), its evolution over time and its implications.

Through this open, evidence-based approach, which integrates qualitative and quantitative methods, the aim is to guide legal and political decision-making through more integrated results that are in line with the challenges posed by the current period of transition.

4.2 *Efficacité* and *Effectivité* as Two Key Measurable Perspectives for Empirical Legal Research

Two key aspects in the context of Empirical Legal Research are the reworking and functionalisation of the concepts of *efficacité* and *effectivité* of norms[379].

The concept of *efficacité* has often been associated with a purely formal dimension, i.e. the ability of a norm to produce valid legal effects. In legal sociology, however, several authors have developed a concept of substantive effectiveness, linked to the consideration of the real effects determined by law[380] .

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[378] A. BLACKMAN, *Map of Empirical Legal Research Topics,* University of Melbourne, Figure 2021 https://doi.org/10.26188/14481765.v1

[379] The expressions *efficacité* and *effectivité* are deliberately retained in French, since their translation into English ("efficiency" and "effectiveness") may blur the theoretical distinction between the two concepts as developed in French legal scholarship.

[380] In classical legal theory, the distinction between validity and efficacy is a fundamental principle of legal positivism. Hans Kelsen explains that validity pertains to a norm's formal conformity with established rules - being valid means it was enacted by a competent authority following proper procedures. Efficacy, however, relates to the norm's actual effects - whether it is obeyed, applied, or enforced. For Kelsen, efficacy is necessary for maintaining the legal order but does not determine its legitimacy: a norm remains valid even if disobeyed, as long as the system

The current evolution of empirical law takes up this legacy and reinforces the idea that *efficacité* is a useful criterion for verifying the ability of law to achieve its objectives and produce measurable changes. From this perspective, therefore, effectiveness consists in investigating the performance of law in the real world.

In addition to *efficacité* – which relates to the ability of law to produce the effects it sets out to achieve – it is important to note the existence of the category of *effectivité***.** The latter logically precedes effectiveness, as it focuses on the practices of applying and receiving law, in other words, on its mise en œuvre.

These coordinates are particularly important for the development of specific legal indicators in the field of environmental law and[381] (including its interactions with the agri-food dimension). This sector is sometimes characterised by a gap between the formal existence of rules and their practical application, with a consequent impact on the achievement of the sustainability goals enshrined internationally in the 2030 Agenda, as well as in national and international political agendas.

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remains minimally effective. However, later theorists have developed a deeper understanding of efficacy, associating it with the real influence of law on social behaviour and institutions. H. L. A. Hart differentiates between the 'internal point of view' of legal officials - who accept the rule of recognition - and the external aspect of social effectiveness, adding an empirical dimension to legal validity. Norberto Bobbio highlights that, although efficacy is a factual concept, it is crucial for evaluating the vitality of legal norms and the discrepancy between law in statutes and law in practice. In a practical and sociological approach, scholars such as Roscoe Pound and Eugen Ehrlich view efficacy as the law's capacity to serve as a living tool for social regulation. These perspectives expand Kelsen's formal approach by emphasising that the substantive effectiveness of law—its real implementation and observable influence—is vital to a comprehensive understanding of legal validity in practice. See, H. KELSEN, *Pure Theory of Law,* Lawbook Exchange, Clark, 2019; H. L. A HART, *The concept of law,* Clarendon Press, 1997.

[381] On this point, reference is made to J. BETAILLE, *Évaluer les effets du droit sur l'environnement: une idée saugrenue pour les juristes?,* in *Revue juridique de l'environnement,* special issue, 2023, pp. 31 ff.

Given that the effectiveness of a regulation requires purely scientific or economic indicators, it is important to note that, in contrast, the category of *effectivité* can only be linked to legal indicators[382] .

While the hard sciences can provide the appropriate measurement tools to quantify how much pollution levels have decreased or increased in a given area after the entry into force of a legal provision aimed at reducing pollution, they cannot help to parameterise and measure how the law is applied, monitored and enforced.

Relying solely on the measurement of *efficacité*, therefore, does not allow us to deduce rigorously whether the increase or decrease in the phenomenon of pollution under consideration can be linked to a specific legal process. In other words, the analysis of *efficacité* alone is not sufficient «to demonstrate whether or not a given result is the result of the rigorous and effective application of the legal rule»[383] .

This raises the question of whether it is possible to measure the law using specific tools, the development of which, in legal theory, has been compared to a Herculean task[384]. However, such a task becomes necessary insofar as contemporary law, in addition to declaring principles or prescribing behaviours, is required to account for its ability to influence real-world dynamics.

The objective of legal indicators of *effectivité*, therefore, is to show and explain the legal difficulties of *implementing* legal instruments, while also recommending any changes deemed necessary to the public and policymakers[385] .

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[382] M. PRIEUR, C. BASTIN, *Mesurer l'effectivité du droit de l'environnement. Des indicateurs juridiques au service du développement durable,* Peter Lang, Brussels, 2021.

[383] *Ibid.,* p. 41.

[384] See C. MCGRATH, *Does Environmental Law Work? How to Evaluate the Effectiveness of an Environmental Legal System?*, Lambert Academic Publishing, Riga, 2010, p. 13.

[385] *Ibid*. pp. 132 ff. On page 133, the Authors state that Legal indicators hold a distinct scientific value within the broader field of empirical environmental research. Through appropriate

A particular study[386] has highlighted how, to date, the issue of legal indicators of *effectivité* is still unsatisfactory due to the presence of a series of

methodologies, they enable the measurement of the effectiveness of environmental law — that is, the extent to which ecological norms are implemented and complied with — by highlighting both the progress and regressions of legal systems over time. Beyond their methodological contribution, these indicators enrich the scientific data used in national and international State of the Environment reports, which have traditionally overlooked the role of law in shaping levels of pollution, biodiversity loss, and ecological protection. The absence of legal dimensions in these reports represents, as some scholars suggest, a severe distortion of the rule of law, since the rule of law today necessarily includes environmental law — what has increasingly been termed the "environmental rule of law." At the international level, legal indicators also strengthen accountability under multilateral environmental agreements. Formally, they can measure the degree of compliance by States Parties with their treaty obligations and help them fulfil their reporting duties. Substantively, they provide evidence-based documentation of how conventions are implemented in practice — identifying strengths, weaknesses, and systemic obstacles in enforcement and governance. Ultimately, legal indicators bridge the gap between law and science, providing empirical visibility to the role of legal frameworks in environmental policy and sustainability governance. By doing so, they enhance transparency, foster informed decision-making, and reinforce the democratic legitimacy of ecological action at both national and international scales.

[386] M. PRIEUR, C. BASTIN, *Mesurer l'effectivité du droit de l'environnement. Des indicateurs juridiques au service du développement durable,* cit, *p*. 105. The work provides a comprehensive and critical mapping of the various types of indicators currently used in the field of environmental governance. Their analysis reveals a striking paradox: although the environmental sector is saturated with measurement tools—statistical, economic, and managerial—none of them truly qualifies as legal indicators in the strict sense. Most existing systems measure the outcomes of environmental policies rather than the processes of law application that make such outcomes possible. According to the Authors, three main categories of indicators dominate the field. The first encompasses environmental performance indicators, developed by international or regional organisations such as the OECD, UNEP, or the European Environment Agency. These instruments (for instance, the Environmental Performance Index or the OECD Environmental Indicators) rely on quantitative environmental data—air quality, biodiversity loss, waste management, greenhouse gas emissions—and thus reflect the efficacité (effectiveness in the instrumental sense) of environmental policies. However, they fail to capture the effectivité of the legal norms themselves, that is, their concrete

indicators (erroneously considered to be indicators of effectivité) that do not measure the conditions of application of the law.

implementation, enforcement, and social reception. A second category consists of economic and governance-based indicators, such as the World Bank Doing Business Index, the Worldwide Governance Indicators, or the World Justice Project's Rule of Law Index. While these instruments introduce some legal dimensions (judicial efficiency, regulatory stability, or perceived corruption), they are primarily rooted in an economic rationality that instrumentalises law as a variable of competitiveness. They quantify the 'ease of doing business' rather than assessing whether the law operates effectively within its normative and institutional framework. Prieur and Bastin denounce this "fetishism of numbers," whereby law is reduced to a statistical artefact instead of being treated as an autonomous mode of regulation. A third group, the so-called "indirect legal indicators," includes measures designed by human rights bodies (e.g., the UN Office of the High Commissioner for Human Rights, the Inter-American Commission on Human Rights, or the ILO). Although these initiatives use legal terminology, they generally record only formal or documentary data—the number of laws adopted, treaties ratified, or judicial decisions rendered—without scrutinising the conditions of their application, control, or sanction. In other words, they describe the existence of law rather than its operational reality. Authors argue that this situation arises from a semantic and epistemological confusion between efficacité and effectivité, often reinforced by the English term effectiveness, which tends to collapse both dimensions. Whereas efficacité refers to the measurable results achieved by legal or policy instruments, effectivité concerns the degree to which law is actually implemented and complied with. The latter is not an outcome but a process—one that unfolds through various legal stages such as the validity, applicability, enforcement, and sanctioning of norms. Existing indicators, being primarily outcome-oriented, thus overlook the very object they purport to measure: the functioning of law as a social and institutional phenomenon. From a methodological perspective, Prieur and Bastin also warn against the tendency toward governance by numbers (Supiot, 2015). Indicators, in their view, should not be conceived as binding metrics but as diagnostic tools—heuristic devices designed to identify dysfunctions, highlight implementation gaps, and inform legal reforms. Law cannot be "governed" by numerical benchmarks without losing its qualitative, interpretive, and value-laden dimensions.

In order to contribute to the resolution of this problem in doctrine, several families of possible legal indicators have been developed. In the present case, six are considered[387] :

1. Criteria of existence and legal sources→ the existence of the rule is a necessary condition; subsequently, its source must be identified on the basis of a profile of the legal act.
2. Criteria of applicability and legality→ applicability of the rule, public awareness of the rule, level of territorial extension.
3. Substantive criteria→ substantive boundaries of the rule: recipients, general or detailed provisions, prohibitions, structural subdivision.
4. Organic or institutional criteria→ institutions that guarantee *implementation* and related means available.
5. →Criteria relating to enforcement controls: existence of administrative, judicial and public controls on the implementation of the regulation.
6. →Non-legal criteria which nevertheless influence the application of the law: effective knowledge of the rule, comprehensibility of the rule, relationship to the rule on the part of those who must apply it, economic acceptability of the rule, etc.

These aspects can be better understood and specified through a graphical representation[388] .

[387] *Ibid*., p. 147. These were developed by Professor Michel Prieur, but others have also been formulated by J. BÉTAILLE, *Les conditions juridiques de l'effectivité de la norme en droit public interne: illustrations en droit de l'urbanisme et de l'environnement*, Thèse de droit, Limoges, 2012.

[388] The present chart is based on the framework developed by M. PRIEUR, *Les indicateurs juridiques- presentation Générale,* in J. FROMAGEAU, A. CHERKAOUI, R. COLL (eds..), *Mesurer l'efficacité du droit de l'environnement à travers des indicateurs juridiques et des analyses de qualité,* UICN, Droit et politique de l'environnement, 91 p. 3

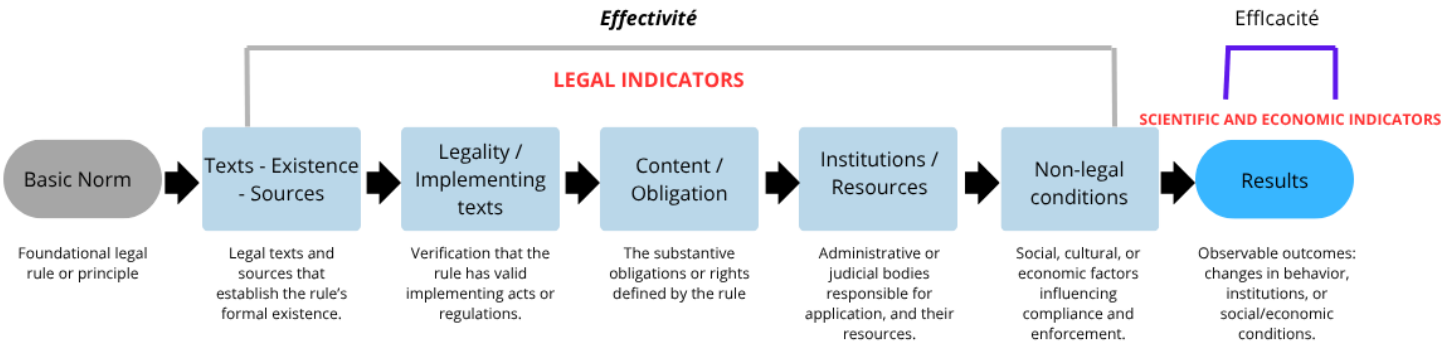

Figure 3 Flowchart about effectivité and efficacité

Based on this sequence of criteria, it is possible to formulate indicators and test them by distributing questionnaires. In the doctrinal framework developed[389] , it is considered necessary to form a team of experts[390] whose task is to choose the field of analysis and its relative scope[391] , draw up an inventory of applicable and

[389] M. PRIEUR, C. BASTIN, *Mesurer l'effectivité du droit de l'environnement. Des indicateurs juridiques au service du développement durable,* cit, pp. 156 ff.

[390] *Ibid., p*. 157. It envisages a body of 10 to 15 members, predominantly legal experts in environmental law – professors, judges, lawyers, or public officials – alongside non-legal specialists such as statisticians, mathematicians, sociologists, political scientists, and historians, in order to ensure an interdisciplinary approach. The members should be appointed in an odd number to facilitate decision-making when consensus cannot be reached. The committee may be supported by a small group of environmental law researchers (e.g., PhD candidates) responsible for document and data analysis. Given the novelty and complexity of the task, initial training sessions are recommended to clarify objectives, methodology, and expected outcomes, thus ensuring the coherence and continuity of the committee's work.

[391] *Ibid.* The committee is expected to determine the specific fields of environmental law to be assessed in terms of effectiveness. Given the vast scope of environmental regulation, it is neither possible nor practical to measure the implementation of the entire body of environmental law. The level of enforcement complexity varies across sectors, depending on the scientific nature of the subject matter or the intricacy of the legal texts. Consequently, the committee should select the

essential sources, develop a questionnaire (consisting of questions and sub-questions) in which each question belongs to a certain scale of values[392] , and establish a panel of respondents[393] . The final part consists of planning the interviews, conducting them and processing the data by statisticians.

domain of law to be evaluated according to specific criteria—such as the topical relevance of the issue, political or social demand, and known challenges in implementation. Once the domain has been identified, the territorial scope of the evaluation (international, national, regional, or local) must also be defined, often depending on the nature of the chosen area. The committee may also establish a priority ranking of environmental domains, based on their importance or urgency, to guide the order in which assessments are conducted.

[392] *Ibid.,* p. 159 ff.

[393] *Ibid.,* p. 160: 'The methodology envisages the creation of a panel of respondents representative of all categories of actors involved in the *effective implementation* of the selected environmental norm or issue. The composition of the panel will vary according to the specific field of environmental law under examination. Following the approach adopted by the *World Justice Project* and its *Rule of Law Index,* the evaluation relies on qualified respondents—individuals with direct expertise and experience in assessing compliance with the law. A typical panel should include 15 to 17 carefully selected participants, reflecting the diversity of the legal enforcement process: (i) officials from the environmental administration responsible for implementation (including at least one inspector); (ii) representatives of those directly subject to the norm (e.g., farmers, industrial operators, artisans, or traders); (iii) two or three representatives of interest groups (such as chambers of commerce or industry, hunters' or fishers' associations, or forest owners); (iv) two environmental NGO representatives (one national and one local/regional); (v) four legal professionals (a solicitor, a criminal judge, a civil judge, and an administrative judge); (vi) one expert from an environmental consulting firm; (vii) one professor of environmental law (not a member of the expert committee); and (viii) two elected officials, one national and one regional or local. Ideally, such panels could be organised by professional survey institutes, capable of reproducing this structure on a larger scale. Depending on the field of law, surveys may be conducted at the international, national, regional, or local level.

4.3 Towards the Development of *Effectivité* Indicators for the Circular Economy

The topic of empirical law and related tools has been introduced in this discussion because it could be a strategic driver in the context of the circular transition.

As has been extensively discussed so far, the legal regulation of the circular economy has the task of translating the scientific challenges related to planetary boundaries and synthesising them into applicable solutions, without neglecting the essential balances between the constitutionally relevant interests at stake. In most cases, the main collector of this challenge is environmental law (and its progressive integration with other rights, from agri-food to IP).

However, when analysing data on the circular economy and attempting to quantify the real impact of public policies and regulatory instruments related to circularity, only aspects of effectiveness are ever touched upon. An example of this is the system of circularity indicators developed by the European Commission's database, Eurostat, 'Circular economy database'[394] . The related monitoring framework is based on quantitative indicators relating to various pillars: production and consumption, waste management, secondary raw materials, competitiveness and innovation, and global sustainability. Each area of reference is linked to specific

[394] See EUROSTAT, *Circular economy database,* at the following link: https://ec.europa.eu/eurostat/web/circular-economy/database

indicators, such as the *Circular Material Use Rate*[395] , *Resource- Productivity*[396] , *Recycling Rate of Municipal Waste*[397] , *Waste Generation per Capita*[398] , as well as various indices on waste production by economic sector.

Although these indicators are a fundamental tool for assessing the efficiency of EU circular economy policies, they merely describe the economic and

[395] The *Circular Material Use Rate (CMUR)* measures the share of recycled materials that are re-introduced into the economy compared with the total amount of materials used in a given year. It provides a quantitative picture of the material circularity of the economic system, indicating the extent to which secondary raw materials replace primary ones. This is an indicator of environmental effectiveness, as it describes tangible outputs in terms of material flows. However, it does not allow one to determine whether such results stem from the effective implementation of legal norms or from market-driven or technological factors external to the legal framework.

[396] The *Resource Productivity* indicator expresses the ratio between Gross Domestic Product (GDP) and Domestic Material Consumption (DMC). It measures the economic efficiency with which material resources are used to generate added value. This is therefore an indicator of economic effectiveness, showing the capacity to decouple growth from material use. Nevertheless, it does not reflect the institutional or legal quality of policy implementation: an increase in productivity may result from innovation or structural economic changes independent of regulatory enforcement.

[397] The *Recycling Rate of Municipal Waste* measures the proportion of municipal waste that is recycled compared with the total amount generated. It reflects the degree of implementation of waste-management policies at national and local levels, yet only from a quantitative perspective. It does not consider the effectiveness of legal rules — for instance, the actual enforcement of recycling obligations, the correct transposition of EU directives, or the administrative capacity of competent authorities. It thus measures the final outcome (*output)*, but not the underlying legal process that produces it.

[398] The *Waste Generation per Capita* indicator calculates the total amount of waste generated annually per person. It serves as a synthetic measure of the efficiency of production and consumption patterns. However, it remains a descriptive and outcome-based indicator: it provides no information about the application or enforcement of legal provisions aimed at waste prevention, nor about the capacity of public authorities to ensure compliance with EU targets.

environmental outputs achieved. Specifically, they do not investigate or measure how legal regulations on circularity have worked to produce those results.

The same applies to various national experiences: in Italy[399] and France[400] , for example, there are only environmental indicators that monitor the transition to a circular economic model.

As a result, the legal dimension of mise en œuvre is still excluded from the statistical basket of circularity rate reports, leaving a significant methodological gap involving various aspects of environmental law.

This leads to the need to develop legal indicators of *effectivité*, capable of measuring the consistency, application and reception of European and national regulations on the circular economy.

The development of legal indicators in the macro-sector of the circular economy makes it difficult to define the scope of the investigation: the term 'circular economy' refers to such a wide and diverse range of areas and sectors that there is a risk of seriously compromising the results. In order to avoid making the relevant basket of legal data involved excessively broad and difficult to manage, it is necessary to define selection criteria.

Although fundamental in classical doctrinal elaborations, the distinction between organic and inorganic circular economy does not seem sufficient to guide the empirical analysis of *effectivité* that we intend to propose. As previously mentioned, there are several sectors in which the two dimensions intertwine

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[399] ISPRA, *Circular economy | Environmental indicators,* 2025, available at the following link: https://indicatoriambientali.isprambiente.it/en/framework/economia-circolare.

[400] SERVICE DE LA DONNÉE ET DES ÉTUDES STATISTIQUES *(SDES), Key Indicators for Monitoring the Circular Economy – 2021 Edition,* French Ministry for the Ecological Transition, Paris, 2021. The report presents eleven key indicators covering the *seven pillars of the circular* economy—raw material extraction and production, eco-design, industrial symbiosis, functional economy, responsible consumption, product life extension, and waste prevention and management. Available at the following link: https://www.statistiques.developpement-durable.gouv.fr/media/4636/download?inline=

(consider, for example, the complexity of agro-industrial circularity strategies, in which organic waste can be involved in recovery operations or in the creation of new materials typical of the inorganic circular economy). Relying on such a dichotomous division could distort the selection of significant legal data, rendering the field of analysis incomplete. In the author's opinion, therefore, it would be more consistent to anchor the construction of indicators to a sectoral logic, based on thematic subsets (such as the textile, agri-food, construction sectors, etc.), which are in turn divided into specific categories.

A further level of complexity is represented by the measurement *of effectivité* in the circular economy sectors, which, as is well known, varies significantly depending on whether a European perspective (based on the application of EU directives and strategies) or a national perspective is adopted. In this specific context, the dimension of *regulatory complementarity* typical of European environmental law should be taken into account.

Since, as stated above, *effectivité* indicators would require a team of experts to define and transpose them into questionnaires, we will limit ourselves to proposing a possible operational scope reduced to the central theme of this paper, namely the valorisation of plant by-products.

4.4. Developing Effectivité Indicators for the Agri-Food By-Products Sector: an Experimental Approach

This paragraph aims to systematise the issue of agri-food by-products through the development of a reproducible model of legal indicators of *effectiveness* (developed according to the model of the six families of criteria identified by French doctrine).

In other words, the intention is to provide a methodological starting point for empirically testing the consistency, applicability and impact of plant by-product law from a multi-level perspective. In the previous chapters the topic was addressed

using a traditional research method and several critical issues were identified (e.g. uncertain definitions, difficulties in application, gaps in the system). Using this methodology, the next step is to translate the implementation framework of the regulatory system involved into figures, identifying the most urgent issues to be addressed in the context of industrial symbiosis.

Below, we proceed to identify specific groups of legal indicators that could be transformed into questionnaires, which will then be reworked with the help of statisticians.

1. The first aspect involves developing criteria for the existence of legal sources (i.e., regulatory texts, ministerial/regional guidelines, official bulletins) at different institutional levels (European, national and local). The measurable indicators can be summarised as follows:
    a) Verification of the existence of a legal definition of by-products
    b) Verification of a legal definition of by-products applicable to plant residues
    c) Verification of vertical consistency between the definitions of by-products (including plant by-products) at the three different institutional levels
    d) Verification of horizontal consistency between definitions of by-products (including plant by-products) in sources at the same level

2. The second aspect consists of developing criteria to measure the degree of feasibility of the rules identified by operators in the sector:
    a) Verification of the clarity of the regulatory conditions for the classification of by-products.
    b) Verification of the operator's accessibility to procedures related to the reuse of these substances (average times, administrative costs, digital forms).
    c) Verification of the degree of transparency of the relevant information.

d) Verification of the uniform application of the regulation

3. The third aspect consists of assessing the quality of the content of the regulations under consideration:
   a) Verification of the scope of application (i.e. permitted operations: reuse, food, feed, bio-based, soil return, bioenergy).
   b) Presence of safety guarantees (food and feed safety, traceability, One Health approach).
   c) Integration with principles related to the circular economy (i.e. prevention and precautionary principles).
   d) Definition of incentive mechanisms

4. The fourth aspect concerns the assessment of the institutional architecture for the valorisation of by-products. Measurable indicators may relate to
   a) Clarity of the division of responsibilities and coordination between the activities involved.
   b) Administrative capacity (resources, trained personnel, lines of command).
   c) Presence of official databases on by-product flows (registers, industrial symbiosis platforms).

5. The fifth aspect concerns enforcement. The objective is to adopt criteria for enforcement checks (i.e. monitoring, inspections, sanctions, litigation).
   a) Verification of the number and frequency of supply chain controls
   b) Verification of types of violations found
   c) Verification of the timing and rates of closure of proceedings
   d) Verification of legal disputes in terms of volume, outcomes, and established trends.

6. The fifth aspect relates to non-legal criteria that affect the application of the rules in question and aims to map the extra-legal factors that could explain the gaps in *effectivité*.
    a) Verification of the technical feasibility of by-product reuse operations (standards, available technologies, infrastructure).
    b) Verification of the technical feasibility of by-product reuse operations (transaction/logistics costs, market demand).
    c) Verification of social acceptance and information on the circularity of by-products (operator knowledge, training programmes).
    d) Verification of the existence of systemic risks: corruption, instability, excessive bureaucracy, etc.

The development of these indicators is not merely a theoretical exercise, but aims to make a practical contribution to the development of empirical measurement tools so that the legal variables discussed so far can be translated into observable data, thanks to collaboration between the legal and statistical-analytical worlds, whose task is to translate the results collected into scores, weights and correlations.

The organisation of a team of experts on this topic (and with a methodology that can be replicated for many other regulatory schemes typical of the circular economy) would make it possible to empirically investigate and quantitatively verify the critical issues discussed in the course of the treatment: the effectivité of the legal framework on plant by-products would appear to be good on average at the regulatory level, but much less solid at the application and operational levels.

The analysis conducted in this paper reinforces the idea of the proactive role that law is called upon to play in the context of the circular transition, demonstrating its strengths and weaknesses in terms of its impact on the economic, environmental and social systems.

Empirical law tools as a whole can become a bridge for dialogue between different scientific sectors and can help guide public institutions towards policies capable of positively governing the transitions caused by the polycrisis.

Conclusions

The research emphasised the structural role of complexity and questioned the function of law within the context of systemic and polycrisis transitions.
In this sense, it was demonstrated that a law which, in some respects, governs complexity with rigid schemes is anachronistic.
Contemporary society requires law to conform to an adaptive system capable of engaging with a plurality of heterogeneous knowledge. The focus was on environmental law and related public policies, which require strategies and tools that respect planetary boundaries while also meeting the economic needs of businesses.

The research question focused on managing ecological transition processes from a regulatory-regenerative perspective rather than a purely regulatory one.
Transitions require law to reinterpret itself: shifting from controller to guide, limiter to enabler and end to true infrastructure for change.

The circular economy paradigm is the main multifaceted tool for achieving this objective, as demonstrated by the analysis of international strategies related to Agenda 2030 and the European Green Deal.

Its constant presence in the multi-level system of legal sources has made it possible to associate circularity with not only a socio-economic model, but also a legal principle. Together with the principles of prevention, precaution and non-regression, this new legal principle outlines the scope of ecocentric yet competitive economic activity, in which the environment is seen as an opportunity for solutions rather than a problem.

All industrial sectors represent the terrain on which this change occurs, and as emphasised in European reports by Letta and Draghi, the European manufacturing sector is pivotal in ensuring the ecological transition is correctly oriented.

Given the need to focus the analysis on a specific context, the agri-food production sector was chosen, as it is the main contributor to environmental emissions and could therefore be a key factor in achieving sustainability.
This enabled some of the problematic issues in this understudied legal sector to be analysed: the circular food economy.
The food sector is one example to which the mathematical formula mentioned at the beginning of the paper can be applied

$$S = \sum_{i=1}^{n} P_i + E$$

The food system comprises a multitude of economic, legal, social, environmental and technological components whose interaction generates emergent properties ('E'), which differ from and are additional to the sum of the individual parts ('Pi').

This paper focuses precisely on the emerging properties linked to the legal regulation of food by-products, particularly plant-based ones.

Many critical issues have emerged, and to summarise them as effectively as possible, the main stages of reflection are reviewed below.

Before analysing the legal framework for plant-based by-products directly, it was considered appropriate to start with the general by-product regulation laid down in the European Waste Directive and transposed into national law.

The analysis revealed that the hybrid legal nature of by-products leads to various issues, ranging from the ambiguous "normal industrial practice" requirement to the absence of uniform criteria at the European level. In addition to the general uncertainty surrounding definitions, legal interpretations are fragmented

between state and local authorities, and there is a lack of professionals specialising in the management of these materials.

These risks distorting competition, hindering the development of a by-product market and fuelling dangerous evasive practices. It should be noted that these critical issues particularly affect SMEs, which, to date, are not incentivised to invest in such sustainable industrial practices.

From a European perspective, the lack of shared EU standards represents a structural weakness of the internal market. The application of the principle of mutual recognition could provide a partial solution to these critical issues, but this would be against the backdrop of a highly fragmented and uncertain framework.

Considering this scenario, the research offers some constructive recommendations. Against the backdrop of a need to harmonise existing regulations, the potential of existing economic and legal instruments must be realised. In other words, circular by-product governance could make better use of market instruments for environmental protection, such as environmental certification mechanisms and green public procurement.

Complementarily, extending IPCEIs (Important Projects of Common European Interest) to by-product and bioeconomy supply chains could promote strategic investments and public–private partnerships for circular industrial infrastructure on a European scale (e.g. circular districts and hubs).

By-products from the food sector encompass all these critical issues and add to them. In this context, circular governance involves using resources in both biological (the organic circular economy) and technical (the inorganic circular economy) cycles.

The issue of valorising vegetable by-products is at the intersection of these dynamics. Following the reconstruction of the legal framework relating to the environment and food, in which plant by-products appear, a fragmented and uncertain picture has emerged. This requires specific intervention to clarify some fundamental aspects of the discipline, especially about promoting greater analysis

of the risks associated with the use of these substances (as has already been done for animal by-products).

The thesis highlights a significant legal vacuum regarding food upcycling practices, which only find limited scope for exploitation in the novel foods channel.

Regarding technical cycles, however, the use of plant-based by-products is linked to circular packaging regulations and raises questions about orienting public policies towards the greater promotion of bioplastics (currently used in minimal percentages).

The issue of functional materials, which are increasingly derived from plant-based by-products, lies at the crossroads between the technical cycle and the biological cycle. These materials require readjustments in terms of food safety and circularity.

As the reintroduction of these substances into the human food chain must comply with food safety requirements, it is believed that the General Food Law does not yet permit the promotion of this transition.

The absence of a circular European regulatory framework for food has a negative impact on consumers' perception of these new ingredients.

Despite these legal gaps, the paper emphasises how a bottom-up approach by public administrations could reverse the trend.

Alongside the strategic tool of public procurement (in the food sector, linked to public food procurement), the value of nudging and moral suasion practices should be emphasised. In this sense, the planning capacity of each public administration takes on bidirectional connotations. While the business world would see specific market demands change, consumption could also be driven to change the cultural paradigm in which by-products are not considered a potential link in the food chain. Regarding this last point, it is important to emphasise the need for public investment in food literacy initiatives.

The above overview would be incomplete without an empirical component. Given the complexity of the underlying challenges, it would be appropriate to assess the *effectivité* of the legislation in the context of the circular food economy.

This thesis proposes a potential course of action, hypothesising a series of legal indicators of *effectivité* linked to the specific issue of by-products. From a cross-cutting perspective, these indicators would constitute a starting point for further research to be conducted in collaboration with statisticians, entrepreneurs, legal practitioners, and institutional representatives.

This would enable the concrete impact of the legislation to be verified in relation to the efficacy results connected to the circular economy, offering the possibility of using new legal semantics that are more inclined towards multidisciplinary dialogue. This is a concrete example of how law can facilitate the transition towards a structurally circular model by acting as a bridge between technology and ecological regeneration.

As this thesis contributes to the European debate on implementing circularity in production and consumption models, the results of this research will be submitted for public consultation on the Circular Economy Act.

The aim is to utilise research as a tool for substantive democracy that is not confined to academia, but rather oriented towards the implementation of collective values, in which the role of law emerges as a catalyst for sustainable regeneration.

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