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Standards and the International Standardization Landscape: Relevance to Plastics

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1. STANDARDS AND THE INTERNATIONAL STANDARDIZATION LANDSCAPE

1.1. Introduction

In recent years, there has been a growing interest in the role standards can perform in tackling plastics pollution. The field of standards and standardization is, however, a complex area inhabited by a multitude of organizations and technical committees populated by anonymous experts. Together, they deal with topics that are often outside the understanding of non-experts, policymakers, or the public.

This paper aims to help policy makers, academia and the interested public obtain a better understanding of the structure and functioning of the international standardization system. It offers an overview of some of the main standardization organizations and current plastics standards, identifies some of the gaps in the landscape of these standards, and highlights the potential role, as well as the limitations, of standards in combatting plastics pollution. The paper also provides recommendations for enhancing the impact and effectiveness of standardization, and highlights the role standards and other instruments could perform in support of a possible future global treaty on plastic pollution.

Part 1 of the paper introduces the concept, main players, and the functions of standards. It gives an overview of the structure of and trends in today's standardization system and some of the main standards development organizations relevant for the field of plastics and plastics pollution. Part 2 provides an introduction to the standards of some technical committees of the main standards organizations working in the field of plastics, with specific relevance to the environment and plastics pollution. Part 3 presents a preliminary mapping of the standards across the main phases of the plastics value chain to identify the current focus and gaps in the coverage of these standards. Part 4 provides proposals on how the contribution of standards and standardization could be enhanced to address key negative externalities generated by the plastics industry and on how standards organizations should re-orient their work to meet these and other environmental challenges. Finally, Part 5 develops a model of how standards, together with other instruments, could help set and verify targets and monitor progress in addressing plastics pollution under a global plastic treaty.

KEY MESSAGES

- A broad range of standards related to plastics have been developed by different standards organizations. Currently, however, these standards do not form a comprehensive and complete set of instruments that can be applied consistently across international markets to combat plastic pollution – from the design phase to end-of-life – or as indicators for measuring progress on addressing plastic pollution.
- Standards are for the most part voluntary instruments that have been developed by industry players and are intended for their use. There is a need for more involvement by governments to define priorities for standard-setting (such as supporting efforts to phase out certain types of plastics, and to promote greater reusability of plastic products, recycling, use of recycled plastics, and non-plastic substitutes) and to provide clear roadmaps for future work. Without such roadmaps, and a complementary regulatory and policy framework, standards on their own cannot provide a solution to the challenge of the plastics pollution.
- Standards could play an important role in supporting a proposed global treaty on plastic pollution, including by establishing targets and tools for monitoring their implementation. For this purpose, standards organizations will need to apply a holistic and comprehensive approach that addresses the whole plastics value chain and all sources of environmental leakage. Further, they should increase their cooperation and look at ways to reduce the current fragmentation between different standards.

1.2. Multiple players in standardization

Standards are developed by many players. Players can be single companies or groups of companies organized as consortia that develop standards for their internal purposes or to capture markets with their products based on a shared design.

At the other end of the spectrum are specialized standards development organizations that bring together multiple stakeholders from industry, business, academia, regulators, consumers, among others. Many of these organizations have a national basis and are constituted as national standards bodies. Regional and international organizations have national bodies as their members. These members operate through national delegations that represent national positions in regional or international standards organizations.

Since the 1980s, another form of standardization organization emerged. Organizations of this type are characterized by the fact that, while being headquartered in one country (perhaps with regional branch offices), they try to attract participation and members (individuals, companies, or a mix of institutions) from around the world.

These organizations have another important characteristic: they typically have a very limited and specific focus, such as a specific field in information and telecommunication technology (ICT) or single agricultural commodities such as cotton, coffee or a specific area such as forest management, often with the objective to improve ecological, social or economic sustainability of production and supply chains and to benefit small producers.

Most standards organizations aim to attract representatives of relevant stakeholder groups in the development of their standards. Most standards organizations pursue the development of standards using documented procedural rules, which generally aim for openness, transparency, inclusiveness and consensus in order to be compliant with widely recognized principles for the development of standards, such as those defined by the International Organization for Standardization (ISO) and the World Trade Organization (WTO). The rules defined by ISO and the WTO are widely used by many standards organizations and in public discourses about standards.

Definitions and legal status of a standard

This section introduces two frequently used definitions of the term "standard" from ISO and the WTO with the goal of arriving at a working definition of the term "standard" that contains elements of both definitions.

ISO and its partner organization, the International Electrotechnical Commission, IEC define "standard" as follows:

> *"Document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.*
>
> *Note: Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits."*[1]

The WTO, in its Agreement on Technical Barriers to Trade (TBT Agreement), defines standard as follows:

> *"Document approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for products or related processes and production methods, with which compliance is not mandatory. It may also include or deal exclusively with terminology, symbols, packaging, marking or labelling requirements as they apply to a product, process or production method."*[2]

Both definitions agree that standards are documents approved by a recognized body and provide rules, guidelines or characteristics. In the ISO definition, standards generally relates to "activities or their results," whereas, in the WTO definition, because of the specific focus of the TBT Agreement, standards are limited to products and their related processes and production methods. The scope of the ISO definition is wider. It includes services and any other topic, such as ethical aspects of business, which are not covered by the WTO-definition.

There are also several other important differences between these two definitions: While the ISO definition emphasizes consensus as the basis for standards, the WTO definition does not specify a need for consensus.[3] Furthermore, the ISO definition leaves the legal status of a standard open: A standard can have a voluntary or a mandatory status; whereas the WTO-definition defines a standard as voluntary (as opposed to a technical regulation, which is mandatory).

Working definition of "standard"

Based on these two definitions, the following working definition and understanding is proposed for the purposes of this paper.

Standards are typically voluntary instruments that address products, processes, systems, and services developed by consensus between different stakeholders.The purpose of standards is to provide for common and repeated use, rules, guidelines or characteristics for activities or their results. Standards should be based on the consolidated results of science, technology, and experience, and aimed at promotion of optimum community benefits. The legal status of standards as voluntary instruments can change, e.g., through their incorporation into law or private contracts.

Functions of standards

In addition to the "rules, guidelines or characteristics for activities or their results" mentioned above, the function of standards are typically seen in:

- defining terminology (providing a "common language");
- providing taxonomies and classification systems;
- setting basic requirements for products and services ("fitness for use");

[1] ISO and IEC (2004), ISO/IEC Guide 2:2004 Standardization and related activities – General vocabulary. ISO and IEC, Geneva, partially available at: https://www.iso.org/obp/ui/#iso:std:iso-iec:guide:2:ed-8:v1:en and https://www.iso.org/obp/ui#search (accessed on 03-05-2021)

[2] WTO (1994), Agreement on Technical Barriers to Trade, Annex 1: Terms and their Definitions for the Purpose of this Agreement, available at: https://www.wto.org/english/docs_e/legal_e/17-tbt_e.htm (accessed on 03-05-2021)

[3] However, one of the six Principles for the Development of International Standards, Guides and Recommendations, which the TBT Committee issued in the year 2000 at the second triennial review of the TBT Agreement requires "Impartiality and Consensus." It should be noted that the six principles formulate requirements for standards that claim to be "international standards" but do not address all types of standards. The six principles can be foundhere:https://www.wto.org/english/tratop_e/tbt_e/principles_standards_tbt_e.htm

- defining test methods to assure requirements are met and test results can be trusted globally;
- assuring compatibility and interchangeability (contributing to network effects);
- reducing the varieties of products and materials;
- assuring health, safety and environmental protection; and
- supporting organizations and other entities in their management practices.

An increasingly important function of standards is innovation. Standards can be carriers for spreading new and collectively reviewed knowledge in the economy and society. They can also provide shared reference frameworks for collaboration between economic, trade, scientific, public, and private entities.

Procedures for the standards development process

All standards development organizations have procedures for the development of their standards. Among the topics defined in such procedures are requirements for approving the initiation of a standardization project and the voting stages until publication. In line with requirements in Annex 3 of the WTO TBT Agreement, many standards development organizations foresee at least one stage of public review with a period of at least 60 days of a draft standard before its final acceptance. This public review period is provided to allow potentially affected parties to express their views on the upcoming standard to avoid, or limit, whenever possible, negative effects on trade or other areas.[4]

Standards and regulations

In line with the WTO's definition, standards are voluntary instruments, but their use can be made mandatory through a regulation. There can be different cases. If a regulation mandates the use of a particular standard (e.g. by referring to the standard in the text of the regulation), this is referred to as an 'exclusive reference' to a standard. Alternatively, an 'indicative reference' occurs where the use of a standard is one way (among others) of meeting the requirements of a regulation.[5] In this second case, the status of the standard remains voluntary. This approach provides the possibility to apply other standards, or entirely other approaches, under the condition that they can demonstrate that they meet the legally binding requirements of the regulation. The indicative reference is typically applied in the European Union, where compliance with respective standards is one way for users to demonstrate that they meet legal requirements without insistence that only specific standards can be used for this purpose.

1.3. An overview of standards organizations

There are different ways of classifying standards organizations. In the following, a distinction is made between

- national standards organizations;
- regional standards organizations;
- international standards organizations; and
- other standards organizations

National, regional, and international standards organizations are sometimes collectively referred to as the "formal" standardization system because these organizations typically have a long history and a well-established role.

National standards bodies

As indicated in the name, national standards bodies (NSBs) or national standards organizations are a focal point for standardization activities in a country and represent national interests in regional and international standards bodies. They are multi-stakeholder and multi-sector organizations. Examples are organizations such as the British Standards Institution (BSI), Standards Australia (SA), the Standardization Administration of the People's Republic of China (SAC), or the South African Bureau of Standards (SABS). Currently, over seventy percent of national standards bodies are governmental or other public organizations,[6] while the remaining are private bodies. As NSBs perform an official function in and for their countries, they have some form of official recognition by their government, even if they are private bodies, either through a standardization law, a formal contract or an agreement with the government in their country. In developing countries, NSBs are often governmental entities, whereas in Europe and the United States they are private.[7]

There is significant variation between different countries in terms of the organization and function of their NSBs. In some countries, most standards development and standardization activities are centrally organized and operated by the NSB. In other countries, the role of the NSB is more that of an administrator and the coordinator, while the development of standards is done by specialized technical or professional organizations. In the United States, the role of the American National Standards Institute (ANSI), for instance, is limited mainly to: a) administering standards activities of several hundreds of autonomous standards development organizations in the United States, all of which develop and publish their own standards; and b) representing the United States in international and regional standards bodies. Among this multitude of standards development organizations, some NSBs have a widely recognized international status and influence, such as ASTM International.[8]

[4] WTO (1994), *Agreement on Technical Barriers to Trade, Annex 3: Code of Good Practice for the Preparation, Adoption and Application of Standards, Clause L., available at:* https://www.wto.org/english/docs_e/legal_e/17-tbt_e.htm (accessed on 03-05-2021)

[5] ISO and IEC (2004), ISO/IEC Guide 2:2004, cl. 11.3.1 and 11.3.2; see also Inklaar, Alex (2009), *Technical regulations. Recommendations for their elaboration and enforcement*. Physikalisch-Technische Bundesanstalt (PTB) and International Trade Centre (ITC), available at: https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_9/9.3_internationale_zusammenarbeit/publikationen/201_Guide_Technical_Regulations/PTB_Q5_Guide1_Technical_Regulations_EN.pdf (accessed on 03-05-2021)

[6] ISO (2019), *Good Standardization Practices*. ISO, Geneva, p. 99, available at: https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100440.pdf. Although these numbers are based on a survey which was conducted in 2009, the ISO Central Secretariat confirmed in a recent email that they are still representative of ISO's current membership (email of 30-03-2021)

[7] ISO and UNIDO (2013), *Fast forward. National Standards Bodies in Developing Countries*. 2nd edition. ISO: Geneva, p. 61, available at: https://www.iso.org/publication/PUB100038.html (accessed on 03-05-2021)

[8] ASTM International was formerly called the "American Society for Testing and Materials".

Regional standards organizations

There are many regional or sub-regional standards organizations that include the NSBs of the region as their members. Some of the regional or sub-regional organizations primarily perform the role of a platform for policy dialogues and exchanges related to standardization, conformity assessment and trade issues. However, some of these regional bodies have developed regional standards to facilitate trade and cooperation in the region. The region most advanced in this regard is Europe, (i.e. European Union (EU), member countries of the European Free Trade Agreement (EFTA) as well as those associated to the EU like Turkey). The two European standards organizations, namely, the European Committee for Standardization (CEN), and the European Committee for Electrotechnical Standardization (CENELEC),[9] have published over 25,000 standards and other documents such as Technical Specifications or Guides, and the European Telecommunication Standards Institute (ETSI) has published over 51,000 standards.[10]

International standards organizations

The most widely recognized international standards organizations are the following:

- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC), and
- International Telecommunication Union (ITU).

At the end of 2020, the ISO had published over 23,500 standards[11] and the IEC around 13,000.[12]

The members of international standards organizations are NSBs or bodies dealing nationally with electrotechnology/electronics or telecommunication. There is also a close cooperation between ISO and CEN (both addressing all subject fields except for electronics and electrotechnology), and IEC and CENELEC (both covering electronics and electrotechnology) through agreements related to information exchange, as well as the joint development of standards intended to become identical international and European standards.[13]

Some intergovernmental organizations also develop standards on certain subject fields. Examples are UN agencies such as the Food and Agricultural Organization of the United Nations (FAO) (where ministries of agriculture represent national members), the World Health Organization (WHO) (where health ministries represent national members), the Economic Commission for Europe (UNECE), and others such as the Organization for Economic Cooperation and Development (OECD).

Other standards organizations

As mentioned in section 1.2, there are hundreds of organizations that develop standards for specific and often highly focused subject fields. Most of these organizations emerged through industry or civil society initiatives, and as a response to frustrations with the slow speed and administrative complexity of the formal standards organizations.

In the Information and Communication Technology (ICT) sector companies are often organized as standards consortia. Other forms of cooperation are groups of individuals who develop standards in organizations such as the Internet Engineering Task Force (IETF) or the World Wide Web Consortium (W3C).

Another very lively field is that of sustainability standards addressing environmental aspects of agriculture, aquaculture, forestry, as well as social and labour conditions under the umbrella of fair trade. Standards on these matters are often collectively referred to as Voluntary Sustainability Standards (VSS). Alongside a vast diversity of sector- and product-specific standards organizations, such as Social Accountability International (SAI), Fairtrade International, the Better Cotton Initiative (BCI), the ISEAL Alliance provides guidance on principles for the development, assurance and impact evaluation of VSS. Other fields of standards include sustainability reporting, which extends financially focused accounting towards non-financial areas represented by organizations such as the Global Reporting Initiative (GRI) or the Sustainability Accounting Standards Board (SASB), and standards like the Greenhouse Gas Protocol, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).

A number of non-governmental standards initatives have a global reach and produce globally recognized and widely used standards. Over time, cooperation has also increased between these and the formal standards organizations, where the latter have incorporated subjects dominant to VSS organizations or ICT consortia, and established collaborative relationships with them.

Adoption of standards

In many cases, NSBs adopt standards that have been developed by international or regional standards organizations as their own national standards. Adoption of such standards reduces the time and resources required for their development, and contributes to consistency between the standards used in different countries and regions. To ensure that a standard meets the requirements of a country or region, it is important that a NSB has participated in and influenced the development of the international or regional standard. Figure 1 shows the different options for adoption: the direct adoption of an international standard (IS) as a national standard (NS); the adoption of an international standard as a regional standard (RS) and then as a national standard; or the adaption of a regional standard as a national standard. As an exception, the NSB of one country can adopt the national standard of another country. In line with the rules for adoption developed by ISO and IEC, if necessary, an adoption can imply technical or editorial modifications to

[9] The number is calculated by combining the numbers for the individual types of publications of CEN and CENELEC. See: https://www.cencenelec.eu/stats/CEN_CENELEC_in_figures_quarter.htm

[10] See the homepage of ETSI at: www.etsi.eu (accessed on 03-05-2021)

[11] See: ISO, *ISO in figures 2020*, available at: https://www.iso.org/files/live/sites/isoorg/files/about%20ISO/iso_in_figures/docs/ISO-in-Figures_2020.pdf

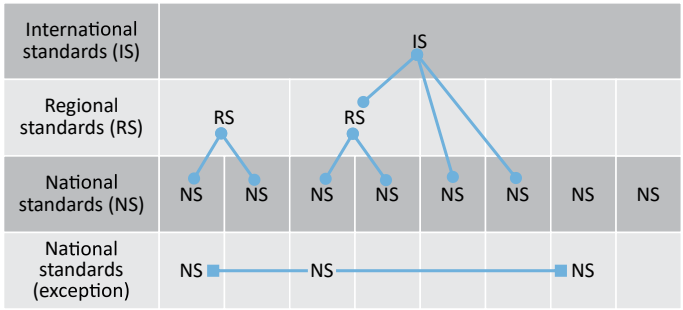
[12] See IEC technical committees and subcommittees, available at: https://www.iec.ch/technical-committees-and-subcommittees#tclist (accessed on 03-05-2021)

[13] On 31 December 2020, the percentage of ISO and IEC standards adopted as standards of CEN and CENELEC amounted to around 45%, see: CEN/CENELEC Annual Report 2020, p. 5, available at: https://www.cencenelec.eu/news/publications/Publications/CEN%20CENELEC%20Annual%20report%202020%20access.pdf (accessed on 03-05-2021)

the original standard, as long as these modifications are clearly identified.[14]

Adoptions typically include the translation of a standard into the language(s) used in the country of the adopting NSB.

Figure 1: Principles of the adoption of international or regional standards as national standards



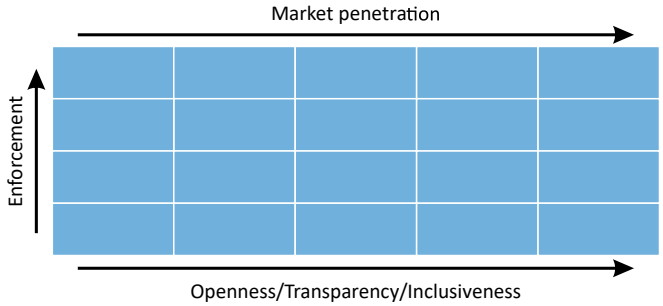
Source: Author's diagram

1.4. Standards mapping

To compare different standards, one can map them over several common dimensions such as:[15]

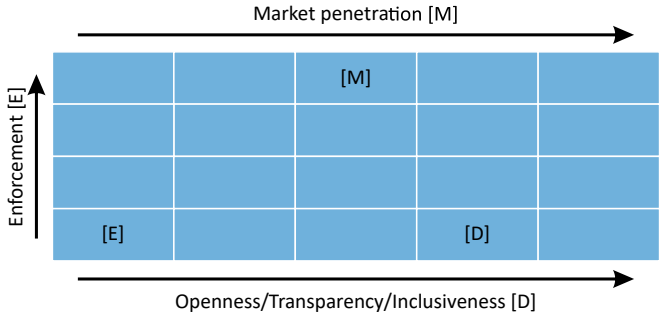
- **Degree of enforcement of the standard:** Has the standard been made mandatory through legislation? Is it imposed by a lead firm in a supply or value chain, making compliance by a firm with the standard a pre-condition for the participation in the value chain?
- **Degree of market penetration:** What is the spread of the standard in (a) market(s)? Has it reached a market-dominating position?
- **Degree of openness/transparency/inclusiveness of the process through which a standard was developed** and, consequently, **the level of consensus** it represents: to what extent did the development process follow the standard principles of openness, transparency, and inclusiveness of relevant stakeholders?

Figure 2: Standards matrix to map aspects of the development, use and impact of standards over three dimensions



Source: Author's diagram

Figure 3: Example of the use of the standards matrix



Source: Author's diagram

Figure 3 presents a case with low (formal or market-driven) enforcement [E], high degree of openness [D], transparency and inclusivity in its development, and medium penetration in certain markets [M].

1.5. The quality infrastructure

Standardization is part of a wider system, often referred to as the quality infrastructure (QI).[16] QI is composed of the following components:

- metrology,
- standardization,
- accreditation,
- conformity assessment (including testing, inspection and certification), and
- market surveillance.

The QI system provides the administrative, managerial and technical infrastructure of measurement (metrology), the development of technical requirements (standards) for products and services, and the verification of these requirements (through testing, inspection and certification) by ensuring that the entities that undertake the verification have themselves the required qualification (competence and facilities) to provide this function (accreditation). Market surveillance aims at verifying those products that have been already placed on the market meet safety and other requirements.

QI is often organized at a national level (NQI), but is based on internationally accepted principles, which assures mutual recognition of requirements and conformity assessment results to facilitate trade and avoid multiple testing at national borders. It is key to the implementation of technical regulations related to product safety, health and environmental aspects of products, their inspection and production methods. QI thus performs an important public policy function with regard to assuring safety of products, their reliability, and health impacts.

[14] ISO/IEC Guide 21-1:2005, *Regional or national adoption of International Standards and other International Deliverables – Part 1: Adoption of International Standards*. ISO and IEC. Geneva 2005, pp. 3-6, available at: https://webstore.iec.ch/publication/11933

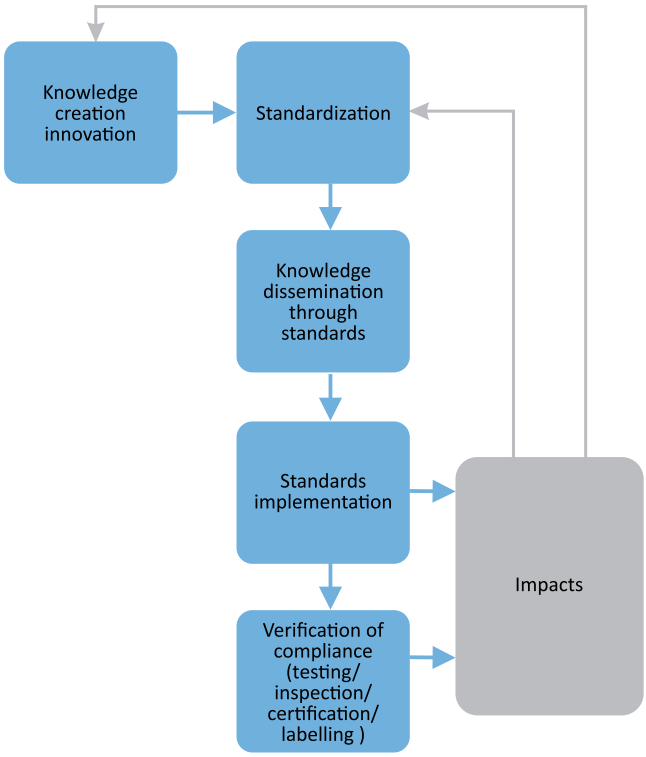
[15] The concept of the three dimensions for the mapping of standards has been developed in and has been adapted from: Thorstensen, Vera, Reinhard Weissinger, Xinhua Sun (2015), *Private Standards—Implications for Trade, Development, and Governance*. E15 Task Force on Regulatory Systems Coherence, available at : https://e15initiative.org/wp-content/uploads/2015/09/E15-Regulatory-Coherence-Thorstensen-Weissinger-Sun-Final.pdf (accessed on 03-05-2021)

[16] See e.g. Kellermann, Martin (2019), Ensuring Quality to gain access to Global Markets. A Reform Toolkit. The World Bank and Physikalisch-Technische Bundesanstalt (PTB). Washington, available at: http://pubdocs.worldbank.org/en/249621553265195570/Full-QI-Toolkit-Report.pdf (accessed on 03-05-2021)

1.6. Standards as a source of innovation through the dissemination of knowledge

Standards can function as an instrument to disseminate new knowledge from research and innovation into economies and societies. As shown in Figure 4, newly created knowledge and innovation is an input into the standardization process. This multi-stakeholder process generates operational knowledge in the form of standards that act as a carrier for knowledge dissemination and generates impacts through their implementation. The implementation of standards may be verified through testing for compliance by independent parties, which may issue certifications and labels that signal to users the compliance of a product, process or service with standards. The use of standards results in experiences, which are channeled back into research initiatives and new standardization projects that may result in the revision, improvement and update of standards.

Figure 4: Generation of impacts through standardization and conformity assessment



Source: Author's diagram

2. STANDARDS AND STANDARDIZATION INITIATIVES RELATED TO PLASTICS

This part of the paper gives an overview of the main standards organizations that develop standards in the field of plastics and environment — ISO, CEN and ASTM International.

2.1. ISO/TC 61 – Plastics

In ISO, technical committee (TC) 61 works on plastics and develops standards related to "nomenclature, methods of test, and specifications applicable to materials and products in the field of plastics including processing (of products) by assembly in particular, but not limited to, polymeric adhesives, sealing, joining, welding." Presently, it comprises of 70 member countries, and addresses the following subject areas through 11 subcommittees (SCs).[17]

ISO/TC 61 was established in 1947 and has so far published more than 700 standards, with around 120 standardization projects currently under development. ISO/TC 61 has eleven subcommittees (SCs) (see Table 1). Most standards produced by TC 61 deal with different types of plastics, their properties and test methods, to determine whether they meet certain requirements. The subcommittee dealing with environmental aspects of plastics is SC 14.

Table 1: Subcommittees under ISO/TC 61 Plastics

Subcommittee reference	Subcommittee title
ISO/TC 61/SC 1	Terminology
ISO/TC 61/SC 2	Mechanical behavior
ISO/TC 61/SC 4	Burning behavior
ISO/TC 61/SC 5	Physical-chemical properties
ISO/TC 61/SC 6	Aging, chemical and environmental resistance
ISO/TC 61/SC 9	Thermoplastic materials
ISO/TC 61/SC 10	Cellular plastics
ISO/TC 61/SC 11	Products
ISO/TC 61/SC 12	Thermosetting materials
ISO/TC 61/SC 13	Composites and reinforcement fibres
ISO/TC 61/SC 14	Environmental aspects

ISO/TC 61/SC 14 – Plastics/Environmental aspects

The SC 14 on Environmental aspects was created under ISO/TC 61 in 2017 and has so far published 31 standards and other types of documents, with 15 documents under development. As stated in the scope of SC 14, the subcommittee deals with "all standardization activities in the field of plastics relating to environmental and sustainability aspects. The focus is on, but not limited to – bio-based plastics, biodegradability, environmental footprint including carbon footprint, resource efficiency including circular economy, characterization of plastics leaked into the environment including microplastics, and waste management including organic, mechanical and chemical recycling."[18]

ISO/TC 61/SC 14 works with five working groups (WGs) (see Table 2).[19] Some of the standards or other documents developed by SC 14 of particular relevance to this paper are introduced below:[21]

[17] See: https://www.iso.org/committee/49256.html (accessed on 03-05-2021)
[18] Recommendation of ISO/TC 61/SC 14 to ISO/TC 61 in document: ISO/TC 61/SC 14 N58, *Report of the plenary meeting on 27-09-2018 in Saitama, Japan* p. 10, dated 04-10-2018
[19] See: https://www.iso.org/committee/6578018.html (accessed on 03-05-2021)

Table 2: Working groups under ISO/TC 61/SC 14 Plastics/ Environmental aspects[20]

Working Group reference	Working Group (WG) title
ISO/TC 61/SC 14/WG 1	Terminology, classification and general guidance
ISO/TC 61/SC 14/WG 2	Biodegradability
ISO/TC 61/SC 14/WG 3	Biobased plastics
ISO/TC 61/SC 14/WG 4	Characterization of plastics leaked into the environment (including microplastics)
ISO/TC 61/SC 14/WG 5	Mechanical and chemical recycling

a. ISO/TR 21960:2020 Plastics – Environmental aspects – State of knowledge and methodologies

This technical report "summarizes current scientific literature on the occurrence of macroplastics and microplastics, in particular in the marine environment, its detection and determination. It gives an overview of current testing methods, including sampling from various environmental matrix, sample preparation and analysis. Further, chemical and physical testing methods for the identification and quantification of plastics are described".

b. ISO/TR 23891:2020 Plastics – Recycling and Recovery – Necessity of standards

This technical report "has been developed to assist all plastics industry stakeholders in the development of new and improved standards for plastic recycling. It gives a short general introduction to plastic recycling, describes the process from feedstock to plastics, different types of recycling technologies, and highlights common problems in relation to recycling of plastic materials and products. Both fossil and non-fossil feedstock are discussed. In Clause 6, existing standards are mapped. In Clause 8, challenges in the transition to a sustainable plastic system are discussed. The necessity of standards is identified in Clause 9."

c. ISO 17422:2018 Plastics – Environmental aspects – General guidelines for their inclusion in standards

This standard "provides a structure for inclusion of environmental aspects in standards for plastic products. It proposes an approach that is directed at minimizing any adverse environmental impact, without detracting from the primary purpose of ensuring adequate fitness for use of the products under consideration.

The guidance provided by this document is intended primarily for use by standards writers. Over and above its primary purpose, this document provides guidance of value to those involved in design work and other activities where environmental aspects of plastics are being considered."

d. ISO 15270:2008 Plastics — Guidelines for the recovery and recycling of plastics waste

This standard "provides guidance for the development of standards and specifications covering plastics waste recovery, including recycling. The standard establishes different options for the recovery of plastics waste arising from pre-consumer and post-consumer sources. It also establishes the quality requirements in all steps of the recovery process, and provides general recommendations for inclusion in material standards, test standards and product specifications. Consequently, the process stages, requirements, recommendations and terminology presented in the standard are intended to be of general applicability".

e. ISO 17088:2012 Specifications for compostable plastics

This standard "specifies procedures and requirements for the identification and labelling of plastics, and products made from plastics, that are suitable for recovery through aerobic composting. The following four aspects are addressed:

i. biodegradation;
ii. disintegration during composting;
iii. negative effects on the composting process and facility; and
iv. negative effects on the quality of the resulting compost, including presence of high levels of regulated metals and other harmful components."

This specification intends to establish the requirements for the labelling of plastic products and materials, including packaging made from plastics, as "compostable" or "compostable in municipal and industrial composting facilities" or "biodegradable during composting….The labelling will, in addition, have to conform to all international, regional, national or local regulations…"

f. ISO 22766:2020 Plastics — Determination of the degree of disintegration of plastic materials in marine habitats under real field conditions

This standard "specifies test methods for the determination of the degree of disintegration of plastic materials exposed to marine habitats under real field conditions.

The marine areas under investigation are the sandy sublittoral and the sandy eulittoral zone where plastic materials can either be placed intentionally (e.g. biodegradable fishing nets) or end up as litter due to irresponsible human behaviour. This depends on their physical characteristics, form and size of the materials, and on water currents and tidal movements."

The standard "specifies the general requirements of the apparatus, and the procedures for using the test methods described."

g. ISO 22526-series:2020 Plastics – Carbon and environmental footprint of biobased plastics

This series of standards "specifies general principles and system boundaries for the carbon and environmental footprint of bio-based plastic products…." The standards are "applicable to plastic products and plastic materials, polymer resins which are based from bio-based fossil-based constituents".

[20] A list of all the current standards and standardization projects of ISO/TC 61/SC 14 can be found here: https://www.iso.org/committee/6578018/x/catalogue/p/1/u/1/w/0/d/0

[21] The information in this overview about ISO standards and other types of deliverables is taken from the introduction or the scope statement of the respective documents. Access to this information is publicly available through the ISO Online Browsing Platform at www.iso.org/obp.

2.2. ISO/TC 122/SC 4 – Packaging/packaging and the environment

Another ISO committee that is relevant in this context is ISO/TC 122 Packaging, and in particular its subcommittee 4, Packaging and the environment.

This subcommittee has published a series of standards (ISO 18601 to ISO 18606) about optimizing the packaging system based on environmental considerations, on the reuse of packaging as well as on material, energy and organic recycling of packaging.[22]

2.3. OTHER RELEVANT ISO STANDARDS AND INITIATIVES

ISO has published many standards on sustainability and the environment.[23] This includes basic standards on environmental management of organizations (the ISO 14000-series), standards on life cycle assessment (ISO 14040 and 14044), standards on greenhouse gas quantification (ISO 14064, 14065, 14067 and others) as well as standards related to climate change adaptation (the ISO 14090-series of standards). A recent initiative in ISO is the new technical committee ISO/TC 323 Circular economy established in 2018, which is in the process of developing standards on "frameworks, guidance, supporting tools and requirements for the implementation of activities of all involved organizations, to maximize the contribution to Sustainable Development".[24]

2.4. CEN/TC 249 – Plastics

In the European Standards Organization CEN, its technical committee CEN/TC 249 deals with various aspects of plastics in the following working groups (WGs) (see Table 3):[25]

Table 3: Working Groups under CEN/TC 249 Plastics

Working Group reference	Working Group (WG) title
CEN/TC 249/WG 2	Plastics warning devises for underground cables and pipelines
CEN/TC 249/WG 4	Decorative laminated sheets based on thermosetting resins
CEN/TC 249/WG 5	Thermoplastic profiles for building applications
CEN/TC 249/WG 7	Thermoplastic films for use in agriculture
CEN/TC 249/WG 9	Bio-based and biodegradable plastics
CEN/TC 249/WG 11	Plastics recycling
CEN/TC 249/WG 13	Wood Plastics Composites (WPC)
CEN/TC 249/WG 16	Welding of thermoplastics
CEN/TC 249/WG 19	Light exposure
CEN/TC 249/WG 21	Profiles for windows and doors
CEN/TC 249/WG 22	Wallcovering panels for building applications
CEN/TC 249/WG 24	Environmental aspects
CEN/TC 249/WG 25	Static thermoplastic tanks for above ground storage of fuel

A close cooperation exists between ISO/TC 61 and CEN/TC 249. In many cases, standards are developed in either ISO or CEN and processed in parallel in the other organization, so that the resulting standard is identical in both ISO and CEN. Over 70% of CEN/TC 249 standards are identical with standards developed by ISO/TC 61.[26]

Of particular interest may be CEN/TC 249 Working Group 9 (WG 9) *Bio-based and biodegradable plastics*, Working Group 11 (WG 11) *Plastics recycling* and *Working* Group 24 (WG 24) *Environmental aspects*.

- WG 9 deals with the "definition of terms, vocabulary and identification means regarding degradable plastics and degradability of plastics. Standardization of test methods for the characterization of the degradability of plastics in various environments. Standardization of specifications for degradable plastics".27

- WG 11 deals with various aspects of the recycling of plastics, including sampling procedures for recyclates of different plastic substances, testing methods for recycled plastics to be used in contact with food, plastic waste characterization, and traceability of recycled plastics to calculate the amount of recycled content in plastics.28

- WG 24 deals with "strategic aspects and coordination of all standardization activities in the field of plastics relating to environmental aspects. The focus is on, but not limited to bio-based plastics, biodegradability, carbon and environmental footprint, circular economy and resource efficiency, microplastics and plastics in the environment, recycling, and waste management."[29]

More information, including the standards of CEN/TC 249 and projects, can be found on the website of this committee.

2.5. CEN/TC 411 – Bio-based products

CEN/TC 411 deals with "(i) the development of standards for bio-based products covering horizontal aspects. This includes consistent terminology, sampling, certification tools, bio-based content, application of and correlation towards life cycle analysis, sustainability criteria for biomass used and for final products, and aspects where further harmonization is needed on horizontal level; (ii) Development of standards for bio-solvents, covering product functionality, biodegradability and, if necessary, product specific aspects not covered under (1)."[31]

More information, including on the standards of CEN/TC 411 and projects, can be found on the website of this committee.[32]

[22] A list of the published standards and ongoing standardization projects of SC 4 can be found here: https://www.iso.org/committee/52082/x/catalogue/p/1/u/1/w/0/d/0

[23] At the end of 2020, 809 ISO standards and ongoing 169 standardization projects, i.e. a total of 978, have been classified into the category of "sustainability and environment". This amounts to around 3,5 percent of the total standards and projects (see: ISO in figures 2020, available at: https://www.iso.org/files/live/sites/isoorg/files/about%20ISO/iso_in_figures/docs/ISO-in-Figures_2020.pdf) (accessed on 14-07-2021)

[24] See:https://www.iso.org/committee/7203984.html

[25] See:https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:6230&cs=17FC5DE6E1DFEDC2859B4C30DAA179DD1 (accessed on 03-05-2021)

[26] Calculated based on the list of published standards of CEN/TC 249 by the author.

[27] See:https://standards.cen.eu/dyn/www/f?p=CENWEB:7:0::::FSP_ORG_ID:19347&cs=1358B3F9360198EAFC7AB2F5834F01314 (accessed on 03-05-2021)

[28] The scope of this WG has been formulated by the author using the abstracts of the publication of the WG, which are available at: https://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:410327,25&cs=19A7CEAB402ADB700B3007331762CDAA4 (accessed on 03-05-2021)

2.6. ASTM D20 – Plastics

ASTM International (formerly, American Society for Testing and Materials) has a plastics committee, ASTM D20, which was formed in 1937. It has so far published over 475 standards developed by 23 subcommittees.

ASTM D20 develops standards for "test methods, specifications, recommended practices, nomenclature, definitions, and the stimulation of research relating to plastics, their raw materials, components, and compounding ingredients, and to finished products made from plastics such as sheets, rods, tubes, pipes, cellular materials, and molded or fabricated articles".[33] The ASTM standards "have and continue to play a preeminent role in all aspects important to the effective utilization of plastics, including specimen preparation, material specifications and methodologies for mechanical, thermal, optical and analytical testing."[34] ASTM D20 also organizes the cooperation between US interests in plastics and ISO/TC 61.

ASTM D20 has two subcommittees that are relevant in this context: ASTM D20.95 Recycled plastics, and ASTM D20.96 Environmentally degradable plastics and bio-based plastics. More information, including a list of the standards under the two subcommittees and their projects, can be found on the ASTM website.[35]

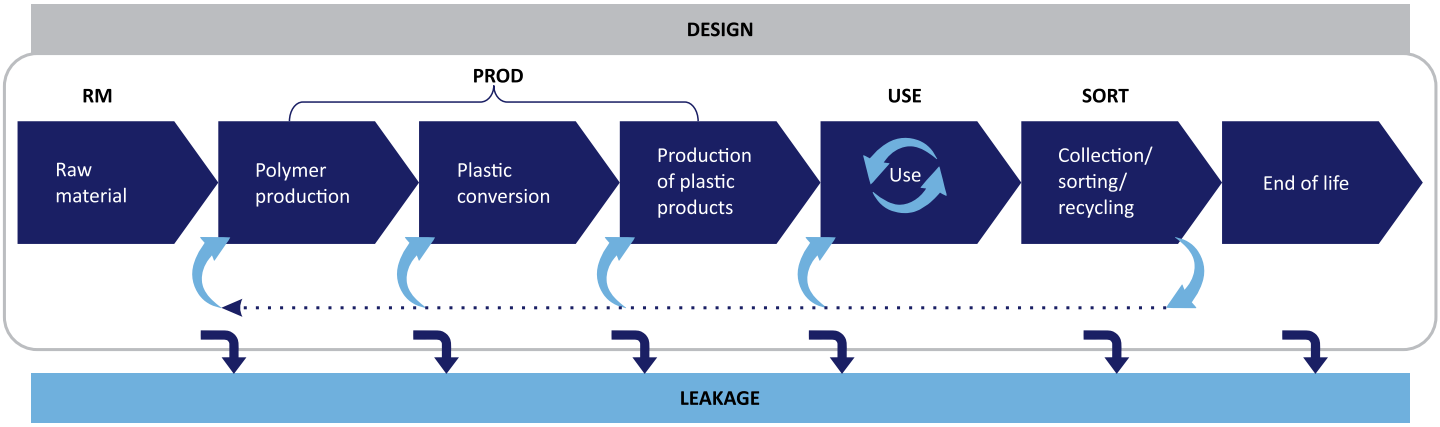
3. PRELIMINARY ANALYSIS OF STANDARDS IN THE CONTEXT OF THE PLASTICS VALUE CHAIN

This part of the paper provides a preliminary analysis of standards in the context of the plastics value chain. The plastics value chain (shown in Figure 5) has four main phases, i.e. raw materials acquisition (= RM), production (= PROD), the use phase (= USE), and collection, sorting and recycling (= SORT) prior to the end-of-life (= EOL) phase. Across these phases, there is a design function, which determines technological, material, product, production and other choices along the value chain.

For the phases to be optimally aligned, the choice of materials and the design of products need to consider functionality and needs across all phases of the value chain, including functionality required after the use phase (i.e. collection, sorting, re-use and recycling) at the beginning of the value chain. This enables efficient and resource-saving choices that facilitate reuse of products, recycling and reuse of materials in production to be achieved. A major challenge that must be addressed is plastics leakage and pollution that occurs throughout the value chain.

Table 4 contains an overview of the main contents of the standards of ISO, CEN and ASTM that were introduced in Part 2 of this paper, mapped to the plastics value chain. A large group of standards addresses different plastics materials and test methods to determine characteristics, the content and the behaviour of plastics (e.g. degradation and disintegration under certain conditions such as exposure to water, seawater as well as in marine environments, which are aspects of leakage into the environment). A specific set of standards, those developed by CEN/TC 411, addresses bioplastics and their behaviour under test conditions aimed at determining biodegradability or compostability. The standards of CEN/TC 249 focus on the behaviour of recycled plastics.

Figure 5: Main stages of the plastics value chain



Source: Adapted from UNEP, Technical University of Denmark (2018), p. 1036

[29] See:https://standards.cen.eu/dyn/www/f?p=CENWEB:7:0::::FSP_ORG_ID:2350485&cs=16A8354F6010EB1B18D1718E860995F0E (accessed on 03-05-2021)
[30] See:https://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:6230,25&cs=11E174A67F5E5FCE25A38D455165ED0CA
[31] See:https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:874780&cs=112703B035FC937E906D8EFA5DA87FAB8 (accessed on 03-05-2021)
[32] See:https://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:874780,25&cs=1D63BAA7EABE56EB230DDAA05D6F2CE70
[33] See:https://www.astm.org/COMMIT/SCOPES/D20.htm (accessed on 03-05-2021)
[34] See:https://www.astm.org/COMMITTEE/D20.htm (accessed on 03-05-2021)
[35] ASTM D20.95: https://www.astm.org/COMMIT/SUBCOMMIT/D2095.htm
[36] UNEP, Technical University of Denmark (2018), *Mapping of global plastics value chain and plastics losses to the environment. With a particular focus on marine environment, available at:* https://wedocs.unep.org/handle/20.500.11822/26745, p. 10 (accessed on 03-05-2021)

Table 4. Analysis of main content elements of selected standards of ISO, CEN and ASTM International

	ISO		CEN		ASTM International		Total
Content	**TC 61/SC 14**	**TC 122/SC 4**	**TC 249 (WGs 9, 11, 24)**	**TC 411**	**D20.95**	**D20.96**	
General	6	1	2	1			**10**
Terminology		1	3	1			**5**
Design							**7**
a. Life Cycle Analysis				2			2
b. Carbon & environmental footprint				2			5
Raw materials	3						**-**
Production							**4**
a. Polymer production			1				1
b. Plastic conversion							
c. Plastic products							3
Materials	3						**66**
a. General							
b. Biomaterials			1	14		1	21
c. Contamination	5		1		5		6
d. Degradation			1			5	6
e. Biodegradation			1			7	8
f. Recycled plastics	8		11		4		15
g. Packaging		10					10
Testing/analysis			6	5		10	**44**
a. General							21
b. Content identification	3		6	6	3		18
c. Separation					3		3
d. Biodegradability	2						2
Labeling						2	**13**
a. General							2
b. Coding		1			1		2
c. Communication		1	2	3			6
d. Declaration	1	1	1				3
Use							**1**
a. General							
b. Reuse		1					1
Environmental conditions							**26**
a. General	9		1			7	17
b. Marine environment	7					2	9
Sort							**18**
a. Waste recovery	1		2				3
b. Collection							
c. Sorting							
d. Recycling	2	5					7
e. Composting	5		1			2	8
End of Life (EoL)				1			**1**
Leakage	18		1			11	**30**

Note: This table analyses selected standards listed in the Annex based on the 'content' elements in the left column. If a standard covers such a content element, the value 1 was assigned. Typically a single standard covers more than one of these elements so that the number for an individual standard can vary between 1 and 4. As a consequence, the numbers in the table exceed the number of the analyzed standards. The numbers in the column 'total' show how often a content element is addressed across the different standards developed by working groups and committees of the three organizations. The rows marked in blue aggregate the elements for the main phases of the value chain introduced in this part of the paper.

Recent studies on pollution across the plastics value chain[37] have shown that the USE-stage is the major contributor to marine plastic pollution, for both macro- and micro-plastics, especially due to "mismanaged municipal solid waste in low-income and lower-middle income countries."[38] For microplastics, the major sources were "abrasion of tyre rubbers, abrasion of road markings and plastics contributing to city dust generation."[38]

Other aspects that are often discussed related to plastics, such as quality categories of recycled plastics for reuse in production, reuse of plastic products, and collection and sorting of plastics, are so far only marginally addressed by any of the standards (e.g. there is one standard about reuse of plastics packaging by ISO/TC 122/SC 4). Another under-represented area is the design of plastic materials and products to facilitate recycling, or providing recommendations for a limited number of additives and avoidance of hazardous substances. To date, the main uses of standards are to determine material content in plastics, bio- or recycled plastics, their behaviour and environmental effects under certain conditions. However, existing standards have so far not systematically addressed key aspects of the plastics value chain. As noted in Part 5 below, a global treaty on plastic pollution could be instrumental to achieve a more complete coverage of the value chain by standards and their use – together with other instruments – in combatting plastics pollution.

4. ENHANCING THE CONTRIBUTION OF STANDARDS AND STANDARDIZATION

The first section of this part of the paper proposes some strategic actions standards organizations could take. The second section, offers specific suggestions for enhancing the contribution of standards to address plastics pollution.

4.1. Proposed strategic actions by standards organizations

As shown in Figure 4, standards can be effective instruments to disseminate new knowledge and innovation in the society and the economy. As the negative side effects of wide scale and increasing use of plastics become increasingly known, standards organizations, and preferably a coalition of them, could help address this challenge in the following three ways:

Apply a value chain and circular economy-based framework as the foundation for standards development

While standards are often highly specific in their focus and developed to address a particular problem (e.g. compostability, test methods for the strength of a certain material), standards organizations should consider the results from large-scale studies about the use of plastics and plastics pollution (e.g. by the World Economic Forum, the Ellen MacArthur Foundation, United Nations Environment Programme, and The Pew Charitable Trusts and SystemIQ).[39]

Standards organizations should base the development of standards on a holistic and systems view of the plastics value chain (Figure 5). This will require overcoming the traditional working style of starting with a focus on highly specific topics, an approach often founded in traditional organizational structures that tend to perpetuate work in silos. The principal orientation should be to contribute towards re-shaping linear value chains into circular value chains by identifying options for reuse, remanufacturing, lifetime extension, recycling, and re-introduction into production. Principles of the circular economy as a holistic framework that aims at retaining goods and materials in use for as long and with a value as high as possible, and comprehensive value chain frameworks, should become the basic paradigm for the development of all standards, not only for standards on plastics. This requires that traditional criteria such as quality, functionality, performance, health and safety of products and materials be systematically extended to encompass ecological footprint and circularity criteria.

Certainly, such a change would not be immediate and would require significant adaptations in the orientation of standards organizations, as well as the experts who are engaged in the development of the standards. However, only such a re-orientation can fully leverage the potential of standardization in support of a fundamental transition towards a circular economy and a sustainable development path.

On plastics specifically, standards should help support sustainable product design choices, reduce the volume of plastics, spur the more efficient use and multiple re-use of plastics, incentivize the design of new types of plastics and plastic products that are more environmentally friendly (biodegradability) and/or achieve significantly higher recycling rates so that plastics can re-enter the production cycle.

A value chain and circular economy framework would also help address and overcome the gaps and deficits in the current set of standards identified in Part 3.

Mutual mapping of standards to determine essential equivalencies

Standards developed by different standards organizations should be mapped against each other to identify common

[37] UNEP, Technical University of Denmark (2018), p. 15; Wilts, Henning, Jennifer Schinkel, Lina Feder (2020), *Prevention of plastic waste in production and consumption by multi-actor partnerships*. PREVENT Waste Alliance and Wuppertal Institute. Bonn; Ryberg, Morten W. et al (2019), *Global environmental losses of plastics across their value chains*, in: Resources, Conservation & Recycling 151 (2019) 104459, available at: https://doi.org/10.1016/j.resconrec.2019.104459 (accessed on 03-05-2021)

[38] Ryberg, Morten W. et al (2019), ibid., p. 1

[39] The following publications are particularly relevant (all accessed on 2021-05-03): World Economic Forum (2016), *The new plastics economy – Rethinking the future of plastics*, available at: http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf; Ellen MacArthur Foundation (EMF) (2017), *The new plastics economy – Catalysing action*, available at: https://www.ellenmacarthurfoundation.org/publications/new-plastics-economy-catalysing-action; EMF (2019), *Reuse – Rethinking packaging,* available at: https://www.ellenmacarthurfoundation.org/publications/reuse; EMF (2020), *Upstream Innovation. A guide to packaging solutions*, available at: https://www.ellenmacarthurfoundation.org/news/new-upstream-innovation-guide-offers-practical-solutions-to-the-plastic-pollution-crisis; The Pew Charitable Trusts and SystemIQ (2020), *Breaking the Plastic Wave. A comprehensive assessment of pathways towards stopping ocean plastic pollution*, available at: https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf

functionalities and requirements. The overview of standards in the plastics sector provided in the Annex reveals a multiplicity of standards, which makes it difficult for standards users to grasp the differences between them. If standards that have been developed by European standards organizations and standards developed by bodies with a stronghold in the United States are essentially equivalent in key requirements, they should be identified as such. This would reduce confusion about diverging standards used in different parts of the world if only limited technical differences exist.

Increase cooperation between standards organizations

In the light of the urgency of addressing plastic pollution, leading standards organizations should increase their cooperation and coordination, including through joint development of standards and joint processes for review of existing standards. Even if there are some differences due to history and regional specifics, reaching an alignment between different standards on essential requirements would provide clearer orientation to markets.

Improve the measurement of the impacts of standards

Standards organizations generally lack systematic knowledge about the impacts of their standards on society, the economy and the environment. Such impacts can be attributed in full or partially to the implementation of standards by companies, public authorities or other users. Statements or claims about the impacts of standards are often either derived from high-level macroeconomic theories or assumptions based on proxy indicators such as figures from the sales of standards, numbers of national adoptions of standards or references to standards in regulations. Although work has been done by some scholars and standards organizations, in particular ISO and the ISEAL Alliance[40] on a methodology for determining impacts, data from systematic and regular evaluation and measurement of the impacts of standards is largely missing. Standards organizations should cooperate in the development of such a methodology for the measurement of standards impacts with a view to implementing it on a significant scale.

4.2. Specific proposals: enhancing the contribution of standards to plastic pollution reduction efforts

The proposals below do not claim to be exhaustive in any form but, if implemented by industry players, would mark a major step forward.

Variety reduction of plastic materials

There are many kinds of plastics, typically mixed with various types of additives and there often exists a high degree of uncertainty about the specific composition of plastic materials or products. The reduction in the variety of plastic materials and of functionally equivalent product types will significantly contribute to simplification, which in turn will increase efficiency in the subsequent life cycle stages such as collection, sorting, reuse and recycling. A key priority is to address challenges upstream in the plastics value chain through design choices with the aim to achieve variety reduction both at the level of materials and of functional equivalent products. This would require a higher degree of standardization both for materials as well as for products, resulting in less material and product variety.

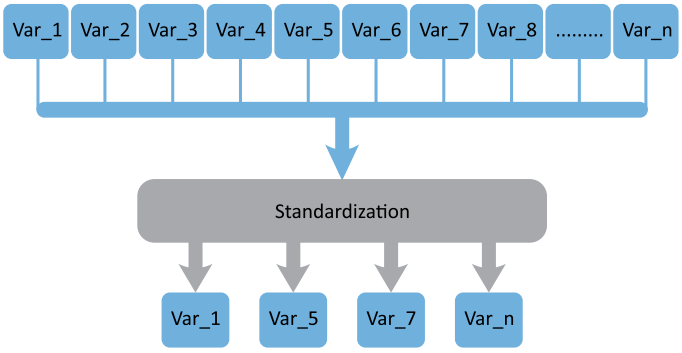
Information about the material composition of plastics should be generated at the beginning of the supply chain and – through a standardized digital materials passport associated with the materials and products using them – be passed through all subsequent life cycle stages. Information about the composition of plastic materials registered in a *standardized digital materials passport* would also ensure transparency about the contents of specific plastic materials and its products.

The basic approach suggested here is to apply an essential function of standardization, which is variety reduction, to plastics production. As shown in Figure 6, variety reduction means that through standardization a number of varieties - among a range of theoretically possible varieties (Var_1 to Var_n) - is given preference in terms of:

- Plastic materials selection
- Plastic products selection

This would make it possible to reduce variability at all later stages, and provide the required transparency for collection, sorting, reprocessing, reuse and recycling. It would also make it more attractive to reuse recycled plastics as its quality could be better assured due to availability of information about the materials used in the preceding loop.

Figure 6: The principle of variety reduction of materials and products



Source: Author's diagram

[40]See ISO (2013), *Economic benefits of standards - ISO Methodology 2.0*, available at: https://www.iso.org/publication/PUB100344.html and ISEAL Alliance (2014), *Assessing the Impacts of Social and Environmental Standards Systems. ISEAL Code of Good Practice. Version 2.0*, available at: https://www.isealalliance.org/sites/default/files/resource/2019-06/ISEAL_Impacts_Code_Version_2.0.pdf (both accessed on 26-07-2021)

Consistent global plastics terminology

Much work has been done on defining key concepts related to plastics, but there is still lack a consistent global terminology and definitions. For example, there is much confusion about concepts such as biodegradability, compostability and bio-based plastics.

Variety reduction in plastic products based on functional equivalence

Consideration should be given to reducing product varieties, such as of plastic bottles and cups, as well as plastic parts in cars, planes or other complex products and replacing them with standardized parts. Such usage of common product types or parts could help all manufacturers meet regular performance requirements. A reduction would also facilitate collection, sorting, reuse and recycling of plastic products by allowing simplified sorting, collection schemes and the required infrastructure. Sustainability, durability, longevity and reusability should be emphasized in the process of variety reduction.

Global taxonomy for quality categories of recycled plastics

Use of recycled plastics is often hampered by uncertainty about the quality and performance of recycled plastics. There is a need for the definition of quality categories and related testing methods to determine the quality of recycled plastics, ensure reliable information about recycled plastics and facilitate their reuse. The reduction of material and product varieties, as suggested above, would significantly reduce the complexity in arriving at the definition of quality categories.

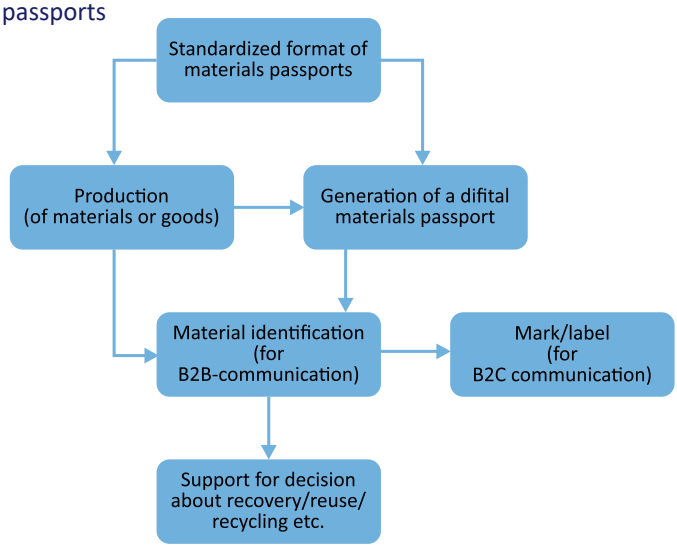
Standardized digital materials passports for plastic products (material transparency)

To provide transparency of the material composition of plastic materials and products, a standardized digital materials passport[41] should be introduced that contains information about all substances, including additives that are part of the composition of plastic products. Standards should define the structure, data format and content of such passports, which should be used by all plastic materials and product manufacturers. Currently, the specific substances mixed in plastics are often unknown, thus making it difficult to determine whether they are hazardous or not, as well as their degree of recyclability. A requirement for a materials passport for plastics would provide transparency along the value chain, including the end-of-use stage of plastic. Such transparency could contribute to the reduction and elimination of hazardous additives in plastic as it would allow scrutiny into the substances used. Materials passports (different from marks and labels) would mainly respond to the need for business-to-business sharing of information and decision-making along the supply chain and product life cycle.

Simple and clear labelling schemes

[41] The concept of materials passports is used, for instance, in the building sector, see: https://www.bamb2020.eu/topics/materials-passports/ (accessed on 03-05-2021)

Figure 7: Generation and use of standardized digital materials passports



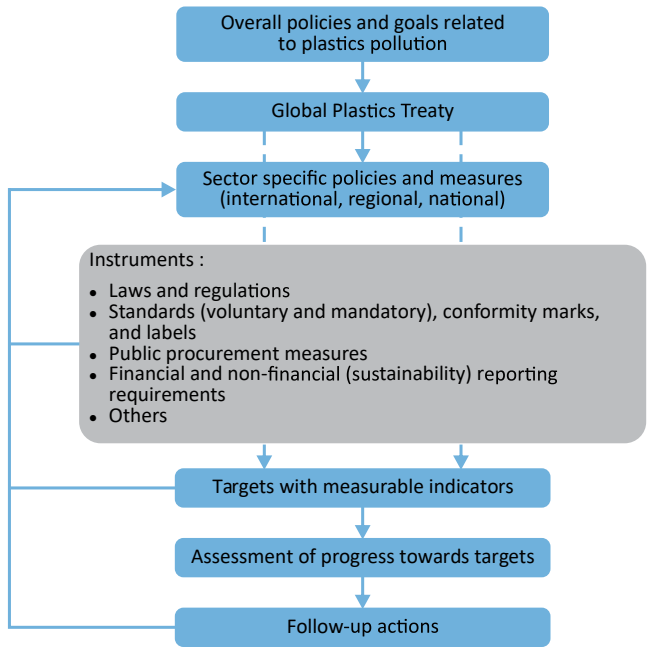
Source: Author's diagram

Simple and clear labelling schemes that express sustainability aspects, including recyclability and content of recycled materials are important for consumers to take informed purchasing decisions. Different from the materials passports, labelling schemes or marks should mainly address the need for business-to-consumer communication and provide consumers with sustainability information, information about recycled content and recyclability of the product.

5. STANDARDS AND OTHER INSTRUMENTS IN SUPPORT OF A GLOBAL TREATY ON PLASTIC POLLUTION

There is growing interest among a broad range of governments in developing a new global treaty to provide a legal framework

Figure 8: Standards and other instruments addressing plastics pollution



Source: Author's diagram

for international efforts to combat plastic pollution. Figure 8 outlines a generic process of how standards, together with other instruments, can be applied in the context of such a global treaty. A global treaty on plastic pollution could also provide the framework to fill gaps in the current set of standards to cover the whole plastics value chain and could trigger more comprehensive implementation of the standards, including monitoring of their effectiveness together with other measures.

To be achieved, the goals of a global treaty need to be translated into sector specific policies and measures at international, regional and national levels, and supported by regulations, standards and other instruments, such as financial, public procurement policies as well as reporting requirements for business and other legal entities. Standards can be used on their own or in support of the other instruments, such as laws and regulations, financial instruments, public procurement measures as well as reporting requirements.[41] The impacts of these instruments and measures will need to be assessed against specific targets in line with the overall goals of the treaty and legal frameworks. The assessment of progress and follow-up actions may require an adaptation of sector-specific policies and measures.

By defining and maintaining a toolbox of recognized and equally functional standards that can be used to achieve targets, the proposed global treaty could leave the choice of specific standards to the implementers. Such an approach would avoid giving preference to certain standards in the treaty itself.

6. FINAL REMARKS

Standards are voluntary agreements developed by groups of multi-stakeholder experts, who cooperate in committees run by standards organizations. The existence of a standard does not assure its use or its large-scale and consistent implementation in markets and industries. First, different standards organizations sometimes develop similar standards, which may compete in the market resulting in the uptake of different standards in different markets and, potentially market fragmentation. Second, to ensure successfull implementation, standards require additional conditions such as an infrastructure and institutional frameworks, including appropriate policies, regulations and consumer awareness. The quality infrastructure, in the form of testing, inspection and certification, plays an especially vital role.

Further, the proposals in this paper for standards that can support a reduction in upstream variety of plastics (both in terms of materials used and product types) and downstream efficiency, can only be implemented through the broad cooperation of a range of industry players and stakeholders upstream and downstream. Such cooperation will require not only voluntary commitments, but also the formulation of regulatory measures and coherent policy objectives by governments, as well as major efforts in end user and consumer education.

Notably, some of these measures would require adaptations in existing regulations and a significant push to ensure that manufacturers engage in such common frameworks. Measures would also have to include incentive and pricing schemes that promote sustainable production and consumption, extension of product lifetimes and support for secondary raw materials markets. Monitoring systems that detect and help address practices contrary to these objectives would be essential. In addition, developed countries will needed need to take action to reduce their own contributions to plastic pollution and to provide technical and financial support to developing countries to tackle the global plastics pollution challenge.

Without pressure from governments, academia, consumer groups and the society, it is unrealistic to expect convergence on such measures and new frameworks, including in regard to new voluntary standards and technical regulations. A global treaty on plastic pollution could play an important role in spurring such cooperation.

[42] Recent developments in the field of financial and non-financial, i.e. sustainability, reporting regarding climate risks, stricter and unified disclosure requirements about impacts on natural and social capital and generally on environmental, social and governance (ESG) topics may evolve into one of a set of powerful instruments driving down environmental impacts of companies and may also result in stronger measures against plastics pollution. In this context see e.g. the contribution by the former CEO of the Global Reporting Initiative (GRI), Mohin, Tim (2021), 'World Changing Ideas. 5 things you need to know about the future of ESG reporting,' in *Fast Company,* 2021-04-21, available at: https://www.fastcompany.com/90627951/5-things-you-need-to-know-about-the-future-of-esg-reporting?partner=rss&utm_source=rss&utm_medium=feed&utm_campaign=rss%20fastcompany&utm_content=rss%3Fcid%3Dsearch&s=09 (accessed on 03-05-2021)

ANNEX – LIST OF RELEVANT STANDARDS OF ISO, CEN AND ASTM INTERNATIONAL (Date: April 2021)

ISO/TC 61/SC 14	Plastics/Environmental aspects
ISO 10210:2012	Plastics — Methods for the preparation of samples for biodegradation testing of plastic materials
ISO 13975 :2019	Plastics — Determination of the ultimate anaerobic biodegradation of plastic materials in controlled slurry digestion systems — Method by measurement of biogas production
ISO 14851:2019	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium — Method by measuring the oxygen demand in a closed respirometer
ISO 14852:2018	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium — Method by analysis of evolved carbon dioxide
ISO 14853:2016	Plastics — Determination of the ultimate anaerobic biodegradation of plastic materials in an aqueous system — Method by measurement of biogas production
ISO 14855-1:2012	Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions — Method by analysis of evolved carbon dioxide — Part 1: General method
ISO 14855-2:2018	Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions — Method by analysis of evolved carbon dioxide — Part 2: Gravimetric measurement of carbon dioxide evolved in a laboratory-scale test
ISO 15270:2008	Plastics — Guidelines for the recovery and recycling of plastics waste
ISO 15985:2014	Plastics — Determination of the ultimate anaerobic biodegradation under high-solids anaerobic-digestion conditions — Method by analysis of released biogas
ISO 16620-1:2015	Plastics Biobased content — Part 1: General principles
ISO 16620-2:2019	Plastics — Biobased content — Part 2: Determination of biobased carbon content
ISO 16620-3:2015	Plastics Bio-based content — Part 3: Determination of biobased synthetic polymer content
ISO 16620-4:2016	Plastics — Bio-based content — Part 4: Determination of biobased mass content
ISO 16620-4:2016	Plastics — Bio-based content — Part 5: Declaration of bio-based carbon content, bio-based synthetic polymer content and bio-based mass content
ISO 16929:2021	Plastics — Determination of the degree of disintegration of plastic materials under defined composting conditions in a pilot-scale test
ISO 17088:2012	Specifications for compostable plastics
ISO 17422:2018	Plastics — Environmental aspects — General guidelines for their inclusion in standards
ISO 17556:2019	Plastics — Determination of the ultimate aerobic biodegradability of plastic materials in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved
ISO 18830:2016	Plastics — Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sandy sediment interface — Method by measuring the oxygen demand in closed respirometer
ISO 19679:2020	Plastics — Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sediment interface — Method by analysis of evolved carbon dioxide
ISO 20200:2015	Plastics — Determination of the degree of disintegration of plastic materials under simulated composting conditions in a laboratory-scale test
ISO/TR 21960:2020	Plastics — Environmental aspects — State of knowledge and methodologies
ISO 22403:2020	Plastics — Assessment of the intrinsic biodegradability of materials exposed to marine inocula under mesophilic aerobic laboratory conditions — Test methods and requirements
ISO 22404:2019	Plastics — Determination of the aerobic biodegradation of non-floating materials exposed to marine sediment — Method by analysis of evolved carbon dioxide
ISO 22526-1:2020	Plastics — Carbon and environmental footprint of bio-based plastics — Part 1: General principles
ISO 22404:2019	Carbon and environmental footprint of bio-based plastics — Part 2: Material carbon footprint, amount (mass) of CO2 removed from the air and incorporated into polymer molecule
ISO 22526-3:2020	Carbon and environmental footprint of bio-based plastics — Part 3: Process carbon footprint, requirements and guidelines for quantification
ISO 22766:2020	Determination of the degree of disintegration of plastic materials in marine habitats under real field conditions
ISO/TR 23891:2020	Plastics — Recycling and recovery — Necessity of standards
ISO 23977-1:2020	Determination of the aerobic biodegradation of plastic materials exposed to seawater — Part 1: Method by analysis of evolved carbon dioxide
ISO 23977-2:2020	Determination of the aerobic biodegradation of plastic materials exposed to seawater — Part 2: Method by measuring the oxygen demand in closed respirometer

ISO/TC 122/SC 4	Packaging/Packaging and the environment
ISO/TR 16218:2013	Packaging and the environment — Processes for chemical recovery
ISO/TR 17098:2013	Packaging material recycling — Report on substances and materials which may impede recycling
ISO/TR 18568:2021	Packaging and the environment — Marking for material identification
ISO 18601:2013	Packaging and the environment — General requirements for the use of ISO standards in the field of packaging and the environment
ISO 18602:2013	Packaging and the environment — Optimization of the packaging system
ISO 18603:2013	Packaging and the environment — Reuse
ISO 18604:2013	Packaging and the environment — Material recycling
ISO 18605:2013	Packaging and the environment — Energy recovery
ISO 18606:2013	Packaging and the environment — Organic recycling
ISO 21067-2:2015	Packaging — Vocabulary — Part 2: Packaging and the environment terms

CEN/TC 249/WG 9	Plastics/Bio-based and biodegradable plastics
CEN/TR 15351:2006	Guide for vocabulary in the field of degradable and biodegradable polymers and plastic items
EN 14987:2006	Evaluation of disposability in waste water treatment plants - Test scheme for final acceptance and specifications
EN 14995:2006	Evaluation of compostability - Test scheme and specifications
EN 17228:2019	Bio-based polymers, plastics, and plastics products - Terminology, characteristics and communication
ISO 13975 :2019	Determination of the ultimate biodegradation of plastics materials in an aqueous system under anoxic (denitrifying) conditions - Method by measurement of pressure increase

CEN/TC 249/WG 11	Plastics/Plastics recycling
CEN/TR 15353:2007	Plastics - Recycled plastics - Guidelines for the development of standards for recycled plastics
CEN/TS 16010:2020	Plastics - Recycled plastics - Sampling procedures for testing plastics waste and recyclates
CEN/TS 16011:2013	Plastics - Recycled plastics - Sample preparation
CEN/TS 16861:2015	Plastics - Recycled plastics - Determination of selected marker compounds in food grade recycled polyethylene terephthalate (PET)
EN 15342:2007	Plastics - Recycled Plastics - Characterization of polystyrene (PS) recyclates
EN 15343:2007	Plastics - Recycled Plastics - Plastics recycling traceability and assessment of conformity and recycled content
EN 15344:2007	Plastics - Recycled Plastics - Characterisation of Polyethylene (PE) recyclates
EN 15345:2007	Plastics - Recycled Plastics - Characterisation of Polypropylene (PP) recyclates
EN 15346:2007	Plastics - Recycled plastics - Characterization of poly(vinyl chloride) (PVC) recyclates
EN 15347:2007	Plastics - Recycled Plastics - Characterisation of plastics wastes
EN 15348:2014	Plastics - Recycled plastics - Characterization of poly(ethylene terephthalate) (PET) recyclates

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EN 15346:2007	Plastics - Recycled plastics - Characterization of poly(vinyl chloride) (PVC) recyclates
EN 15347:2007	Plastics - Recycled Plastics - Characterisation of plastics wastes
EN 15348:2014	Plastics - Recycled plastics - Characterization of poly(ethylene terephthalate) (PET) recyclates

ASTM D20.96	Plastics/Environmentally degradable plastics and bio-based plastics
D3826-18	Standard practice for determining degradation end point in degradable polyethylene and polypropylene using a tensile test
D5071-06(2013)	Standard practice for exposure of photodegradable plastics in a xenon arc apparatus
D5208-14	Standard practice for fluorescent UltraViolet (UV) exposure of photodegradable plastics
D5272-08(2013)	Standard practice for outdoor exposure testing of photodegradable plastics
D5338-15(2021)	Standard test method for determining aerobic biodegradation of plastic materials under controlled composting conditions, incorporating thermophilic temperatures
D5511-18	Standard test method for determining anaerobic biodegradation of plastic materials under high-solids anaerobic-digestion conditions
D5526-18	Standard test method for determining anaerobic biodegradation of plastic materials under accelerated landfill conditions
D5988-18	Standard test method for determining aerobic biodegradation of plastic materials in soil
D6400-19	Standard specification for labeling of plastics designed to be aerobically composted in municipal or industrial facilities
D6691-17	Standard test method for determining aerobic biodegradation of plastic materials in the marine environment by a defined microbial consortium or natural sea water inoculum
D6866-21	Standard test methods for determining the bio-based content of solid, liquid, and gaseous samples using radiocarbon analysis
D6868-21	Standard specification for labeling of end items that incorporate plastics and polymers as coatings or additives with paper and other substrates designed to be aerobically composted in municipal or industrial facilities
D6954-18	Standard guide for exposing and testing plastics that degrade in the environment by a combination of oxidation and biodegradation
D7444-18a	Standard practice for heat and humidity aging of oxidatively degradable plastics
D7473/D7473M-21	Standard test method for weight attrition of non-floating plastic materials by open system aquarium incubations
D7475-20	Standard test method for determining the aerobic degradation and anaerobic biodegradation of plastic materials under accelerated bioreactor landfill conditions
D7991-15	Standard test method for determining aerobic biodegradation of plastics buried in sandy marine sediment under controlled laboratory conditions

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