UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Plastic Pollution

The pressing case for natural and environmentally friendly substitutes to plastics

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EXPLANATORY NOTES

Reference to "dollar" and "$" indicates United States dollars, unless otherwise stated.

Use of a dash (–) between dates representing years, e.g., 2015–2017, signifies the full period involved, including the initial and final years.

Reference to "t" is made for metric tons.

Reference to "M" is made for millions.

Reference to "kg" is made for kilograms.

To reflect the closest estimate for data, decimals and per centages are rounded off. Numbers are rounded to the nearest dollar, unless otherwise stated.

Decimals and per centages in this document do not necessarily add up to totals because of rounding.

Workshop on sustainable and effective substitutes and alternatives for plastics:

06 December 2022, 10:00 - 13:00 hrs
Geneva, Switzerland

ACRONYMS AND ABBREVIATIONS

ALDFG	Abandoned, lost or discarded fishing gear
CIEL	Center for International Environmental Law
EIP-AGRI	European Innovation Partnership for Agriculture Productivity and Sustainability
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas
HDPE	High-density polyethylene
HS	Harmonized System
LDC	Least developed countries
LDPE	Low-density polyethylene
MFN	Most-favoured nation
NTM	Non-tariff measure
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
RCA	Revealed comparative advantage
SDG	Sustainable Development Goals
SMEP	Sustainable Manufacturing and Environmental Pollution
SPI	Sustainable Products Initiative
SPS	Sanitary and phytosanitary
SRT	Squid ring teeth
SUP	Single use plastic
TESS	Forum on trade, environment and SDGs
TBT	Technical barriers to trade
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
WCO	World Customs Organization
WEF	World Economic Forum
WTO	World Trade Organization

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Executive summary

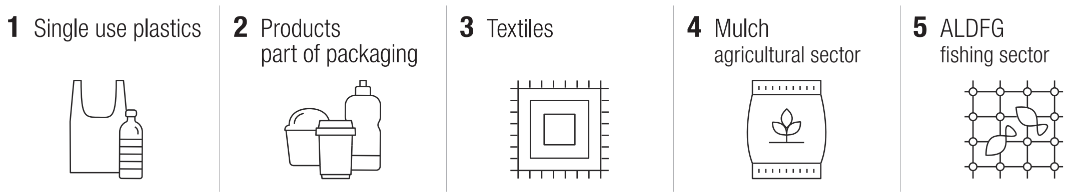
The implications of plastic pollution have gained importance at all levels over the last few years, from individual consumers to national and international policy makers. Current trends are not in favor of reducing such pollution, on the contrary, as the global plastic production trend is increasing. It is estimated that there were **369 million tons of plastics traded in 2020 alone, which is $1.2 trillion in value, a significant increase from $933 billion the year before** (UNCTAD, 2022d). Plastics' omnipresence has pushed waste management capacities to their limits; thus, it is of the utmost importance to identify what materials or products could successfully substitute plastics and how to implement this transition.

There have been many international efforts put into action to tackle the problem of plastics, with the majority still focusing on downstream strategies. At the same time, there are a **growing number of initiatives addressing and consequently stimulating changes throughout the whole plastic life cycle** in a move towards the development of circular economies, including strategies to reduce resource use as well as material-shift towards substitutes to plastics throughout value chains.

For efforts of substituting plastics to succeed, the definition of what exactly a plastic substitute is needs attention. **Plastics substitutes can be considered** all natural materials from mineral, plant, animal, marine or forestry origin that have similar properties of plastics. They do not include fossil fuel-based or synthetic polymers, bioplastics, and biodegradable plastics. Plastic substitutes should have lower environmental impact along their life cycle (e.g., natural fibres, agricultural wastes, and other forms of biomass). Depending on the case, they should be biodegradable/compostable or erodible, and should be suitable for reuse, recycling, or sound waste disposal as defined by national, regional regulations or in internationally agreed definitions. They can include by-products. Plastic substitutes should not be hazardous for human, animal, or plant life.

One of the crucial aspects of introducing a substitute to plastic is not to aggravate the environmental impact or to cause harm in any other way. **Impacts of potential plastic substitutes, such as water or land use, greenhouse gas emissions, and human health, are best assessed with a standard set of indicators under life cycle analysis (LCA).** Most suitable substitutes are usually found among locally available materials with a high rate of reusability. The longer their reusability, which marks a step away from today's throwaway culture stimulated by plastics, the higher the resulting positive impact of the substitutes.

Although there are new (some highly innovative) materials and products being developed and entering the market, a defined list of plastic substitutes does not exist (yet). Altogether, there are five clusters identified as those that contribute the most to plastic waste and put a significant pressure on countries' waste management system capacities:



A Harmonized Commodity Description and Coding System (HS) is thus used to map substitutes to products from these clusters as it offers an internationally shared approach to classifying products. The HS codes have many benefits but also some limitations, such as clarity (especially relevant for newer products) and level of aggregation (many HS codes used for substitutes also include plastics). In addition, some innovative materials being under research and/or development, couldn't be identified using today's HS codes system. The report **mapped an illustrative list of 282 HS codes for plastic substitutes**, of which many are concentrated under HS chapters: Wood and articles of wood; Pulp of wood or other fibrous cellulosic material; Paper and paperboard; Wool, fine or coarse animal hair, yarn and woven fabric; Vegetable textile fibres, paper yarn and woven fabrics of paper yarn, and Aluminium.

Based on this list, the **trade value of plastic substitutes in 2020 was $388 billion, of which two thirds represents exports of raw materials ($258 billion)**. In terms of total global goods exports, the share of plastic substitutes (almost 2 per cent share) is less than that of plastics, which represented 5 per cent of global exports in 2020. This indicates space for adequate policy support and incentives. Currently, for example, the average unit price of plastics is much cheaper than their substitutes. So, the price incentive is often against substitution. Given current conditions, market forces would themselves reproduce the unsustainable use of plastics we currently see.

Trade policies and their instruments, such as tariffs and non-tariff measures, can influence the course of development of plastic substitutes. According to the trade data for the list of 282 HS codes of plastic substitutes, **plastic materials and products generally enjoy lower tariffs and are concentrated below 10 per cent, while product substitutes range between 5 per cent and 25 per cent**. So, in addition to the current unit price difference, higher tariffs are posing an additional challenge to making plastic substitutes economically viable. A more detailed comparison between some selected plastic products and their substitutes reveals a clear difference between very specific substitutes: for example, paper straws have a global average tariff rate of 13.3 per cent, while plastic straws' global average tariff is 7.7 per cent.

Looking forward, there are a variety of actions and tools that can facilitate the transition to substitute materials. These include addressing tariffs and non-tariff measures, revising HS codes to better track trade flows, diversifying and expanding financial instruments to support research and development of innovative materials, and reaching consensus on a standardized set of life cycle indicators to inform decisions on the most appropriate substitutes. With the appropriate incentives, the movement towards plastic substitutes can also be viewed as an economic development policy. This shift can benefit developing economies by fostering the growth of new productive capacities, increasing exports of various types of substitutes, and creating higher-value employment opportunities, while also taking into consideration the potential impacts on women and changes in labor structures.

Introduction

The impact of plastic pollution has reached alarming levels. Out of the 369 million tons of plastic waste generated every year about 11 million metric tons enters the ocean (UNCTAD, 2022d and UNEP, 2022). This number is projected to triple by 2040 if no measures are adopted to halt that pace (The Pew Charitable Trust and Systemiq, 2020). The situation is very concerning as current levels of plastic waste are already damaging marine and terrestrial ecosystems, compromising human health, as well as the food web.

Most plastic materials never fully disappear, but only break down into smaller particles. These micro-particles can be found everywhere, including in the aquatic and terrestrial food systems (Allen et al., 2022). In addition to the ingestion of aquatic food contaminated with microplastics, nano plastics may be absorbed into tissues or cells of other foods (SAPEA, 2019). Humans are also exposed to microplastics by inhaling airborne particles and fibres found in indoor and outdoor environments (OECD, 2020). Moreover, globally, over 84 per cent of drinking water samples are now estimated to contain microplastics (SMEP, 2022a).

Plastic pollution also has a negative toll on countries' economies as it impacts the ability to create jobs and revenue in areas that depend on clean ecosystems, such as tourism and fisheries. Governments face significant and growing costs to dealing with plastic refuse with already over-burdened infrastructure – sewage systems and roads may become clogged with plastic, increasing the risk and intensity of floods (UNCTAD, 2019). Annual costs of plastic pollution are estimated at $2.2 trillion, including $1.5 trillion in ocean damage, $695 billion in greenhouse gas (GHG) emissions, and approximately $25 billion in land pollution (SMEP, 2022a).

In March 2022 the United Nations Environment Assembly adopted a resolution on plastics pollution that calls for countries to promote material substitutes to plastics through national policy instruments while on the multilateral level efforts should be made to further develop the Harmonized System (HS codes (UNEA, 2022). The resolution emphasizes the promotion of plastic substitutes to not only reduce a direct environmental impact, such as ocean pollution, but also to incentivize innovations, an ocean and a circular economy, and new industrial capacities, particularly in developing countries.

The focus of this paper is to identify an extended list of environmentally friendly plastics substitutes and their corresponding clusters that are responsible for plastic waste and that pose a great pressure on countries' waste management system capacities. Building on the substitutes identified, the paper further assesses trade-related flows and policies underpinning substitutes using the HS codes. The paper also provides an insight into trade flows, a summary of findings and advice on potential next steps.

Due to data constraints, it is not methodologically feasible to fully explore the environmental impact of listed potential substitutes. Nevertheless, challenges remain when making decisions about the varying environmental impacts of replacing plastics with plastic substitutes, highlighting relevant arguments from existing LCA studies that analyze various plastic substitutes (SMEP, 2022b; UNEP, 2021; World Bank, 2022; McKinsey, 2022). It also offers, in a nutshell, a state of the situation of plastic pollution of each of the clusters and the current potential for the development of plastic substitutes, providing an overview of critical pollution aspects of the latter. This publication then draws some overarching conclusions and recommendations to guide more informed decision-making towards a sustainable material transition which could also bring about social gains through expanded market opportunities.

1

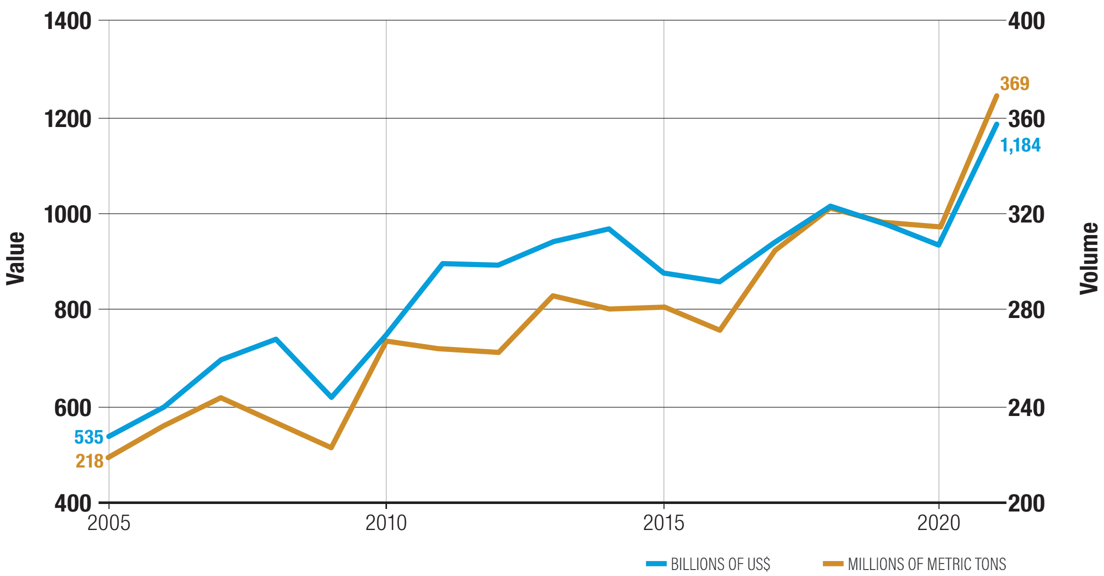
PLASTICS AND THE ENVIRONMENT
A PRESSING GLOBAL ISSUE

1. Plastics and the environment: a pressing global issue

Today it is well established that the current levels of plastic pollution are unsustainable, cause serious harm to human health, livelihoods, food systems, and to the environment. Unsurprisingly, due to the long-lasting nature of polymers, all plastics ever produced are still with us in different formats from finished products and recycled products to a wide array of wastes from macro to nano particles, today found in almost all ecosystems (Geyer, Jambeck, Law, 2017). Evidence is also growing about the significant impact it has on greenhouse gas (GHG) emissions and climate change (Royer, Ferrón, Wilson, and Karl, 2018). As well as the fact that plastic pollution not only has multiple dimensions (air, soil, freshwater and oceans), but it also occurs across the life cycle of plastics production, use and disposal and affects all countries, including those that are not the main producers or users of plastics.

Unless the current level of plastic production is halted, it is expected to increase significantly over the coming years.[1] The current situation is untenable and has triggered efforts by governments, industry, and civil society groups to address the multiple dimensions of plastic pollution across the life cycle of plastics. It is important to keep in mind that the challenges are significant – due to its price and malleability – it is used in virtually all industries at all stages of their value chains (Vaca and Deere, 2021); as shown by the most recent UNCTAD trade data in Figure 1 below, more than 369 million tons of plastics were traded in 2021 alone, representing about $1,184 billion in value, and 5.3 per cent of world trade (UNCTAD, 2022d). goods and services.

Figure 1. Value and volume of global plastic goods exports between 2005 and 2021



Source: UNCTAD Plastic Trade Stats (2022d)

1 For example, new Shell ethane cracker being constructed in Pennsylvania could emit up to 2.25 million tons of CO2 each year; a new ethylene plant at ExxonMobil's Baytown, Texas, refinery could release up to 1.4 million tons –annual emissions from just these two facilities compare to adding almost 800,000 new cars to the road. These are only two among more than 300 new petrochemical projects being built in the United States of America alone—primarily to produce plastic and plastic feedstocks (CIEL, 2019). Outside the United States of America, plastic production growth is expected from industries in Africa, the Middle East and developing Asia (http://www.sela.org/en/events/e/71932/promoting-substitutes-and-alternatives-to-plastics)

1.1 Pollution across the plastic life cycle

The impact of plastic in the environment is subject to many factors. It depends on the type of primary plastic used, the polymer-product combination in a plastic product, and the capacity of countries to collect and dispose of plastic waste (Vaca and Deere, 2021). Some common patterns exist at the global level and at each stage of the plastics value chain. Studies have found that the first stage of the plastic life cycle, extraction and refining to produce plastic, contributes to the highest source of GHG. Today, 98 per cent of plastics in use are plastics made from crude oil or gas,[2] which requires high energy consumption for refining[3] (OECD 2022a, CIEL 2019). Plastics made from recycled material, which emit less GHG than virgin plastics, only accounted for 9 per cent of global plastics used and about 22 per cent was misused by 2019 (OECD 2022b). The next production stage, manufacture of plastic, is both energy intense and GHG emissions intensive due to the cracking of alkanes into olefins, the polymerization and plasticization of olefins into plastic resins, and other chemical refining processes (CIEL, 2019).[4] What is more, plastics manufacturing includes the use of chemical additives that may also act as a sink and means of transportation for persistent organic pollutants (POPs). Adsorbed chemicals found on sampled plastic debris include chemical additives and trace metals (OECD, 2022).

As for plastic collection and disposal, the inadequate management of plastic waste has led to increasing levels of contamination of the air, soil, freshwater, estuarine and marine environments. About 75 per cent of all plastic produced in history has become waste (UNCTAD, 2019a). This situation is observed even in countries with excellent waste collection and management systems and high public support for material recovery. This is because it is difficult to recycle all plastic waste and the majority remains left in landfills and in some cases reaching lakes, rivers, and ocean basins (Vivas and Barrowclough, 2021). It is estimated that improper plastics management has contributed towards GHG emissions of approximately 1.7 gigatons of carbon equivalent (GtCO2e) and about 2 per cent of total global carbon emissions by 2022 (UNCTAD, 2021).

Globally, a century of waste is accumulating in landfills, agricultural soils, streets, waterways, rivers, and the ocean, as 79 per cent of plastic is dumped in the environment and the flow keeps growing – for example, more than 8 million tons of plastic waste leaks into the ocean each year. In fact, out of the estimated 6.3 billion tons of global plastic waste produced; only about 9 per cent has been recycled, 12 per cent has been incinerated – this leads to extremely high emissions of greenhouse gas and is the primary driver of emissions from plastic waste management (SMEP, 2022). These figures are concerning not only because of the toxicity of plastics, but because of the longevity of plastics – which in some cases is particularly problematic. For example, single-use plastic products like low-density polyethylene (LDPE) plastic bags and high-density polyethylene (HDPE) bottles could have estimated half-lives of 5-250 years on land and 3-58 years in marine environments, while rigid plastics such as high-density polyethylene (HDPE) pipes need thousands of years to completely degrade, with an estimated half-life of 1,200 years (Chamas et al., 2020). The degradation period depends on their type and on external environmental conditions.

Plastics also contribute to climate change when plastic photodegradation (exposure to light) triggers the production of GHGs, which consequently increases with the quantity of plastic produced and accumulated in the environment (WEF, 2022). Impact grows as the surface area of plastic increases due to weathering and breakdown in the ocean as there is a tremendous increase in methane and ethylene off-gassing. For example, LDPE powder off-gases methane 488 times more rapidly than when the same weight of LDPE

2 Sources include direct emissions, like methane leakage and flaring, emissions from fuel combustion and energy consumption in the process of drilling for oil or gas, and emissions caused by land disturbance when forests and fields are cleared for well pads and pipelines.

3 Where oil is the primary feedstock for plastic production, extraction and refining attributable to plastic production are the main source of approximately 108 million metric tons of CO2e per year

4 For example, globally in 2015, only the emissions from cracking to produce ethylene were 184.3–213.0 million metric tons of CO2e, amount of CO2e that can be compared to as many as 45 million passenger vehicles driven in one year.

Box 1. Plastic life cycle

The life cycle of most plastics begins with the extraction of fossil oil and gas (i.e., virgin plastics) that yield the feedstocks. Only between 1 to 2 per cent of plastics are derived from bio-based feedstocks or recycled plastic polymers (WEF et al., 2016). After extraction, these fossil fuels are refined and used by the petrochemical industry to produce polymers. These polymers usually take the form of resin pellets or fibres and are widely described as "primary plastics." This first stage of the plastics lifecycle produces some 30 main types of primary plastic polymers (Barrowclough et al., 2020). These polymers usually include, or have added to them, chemical additives such as Polycyclic aromatic hydrocarbons (PAH)s, polychlorinated biphenyls (PCBs), and dichlorodiphenyldichloroethylene (DDE), a breakdown product of Dichloro-diphenyl-trichloro-ethane (DDT)) and which may pose health hazards. These are utilized for the manufacture of intermediate or final plastic products (Barrowclough et al., 2020). After consumption, the final stage of the life cycle of plastics includes the collection, sorting, and disposal of plastics. The disposal stage of the life cycle can include reuse, recycling, incineration, landfilling, and open burning of plastics. Selection of disposal depends on a large array of factors as plastic products can be made of a set of materials—in some cases, over nine different types of materials— mixed together, which are then incompatible with each other in the recycling stream (Feber, 2022). These various plastic products have different lifetimes, recyclability, and risks to the environment and to human health – all of which call for a granular perspective.

Source: Compiled by the authors.

is in pellet form. Moreover, exposure of plastic to direct sunlight (not submerged in water) produces even more of the gases – in the case of LDPE, it releases approximately two times more methane and 76 times more ethylene when exposed to air than when incubated in water (CIEL, 2019). Finally, the production of hydrocarbon gases, although small, continues indefinitely in the absence of sunlight as plastic continues to break down, exposing yet more surface area to reactive processes (CIEL, 2019).

This reality is observed across the world, but it is especially pervasive and visible in coastal countries – including those that are not producing plastic or where plastics consumption is not high. Costal countries are witnessing plastic bottles, plastic bags, other single use plastics and abandoned fishing gear contaminating their shores. These are cause of entanglement of aquatic life in floating plastic debris and of increased mortality following the ingestion of plastics by marine species –due to the chemicals these have or starvation as this causes the false sense of satiety. This is the case of, for example, turtles, fish (including protected species and species with high commercial value), marine mammals, seabirds, and is reducing marine biodiversity (OECD, 2022a, Vivas and Barrowclough 2021, GGGI 2022, FAO 2016).

Furthermore, plastics slowly breakdown into microplastic components, nano plastics particles, and micro(nano)particles including toxic chemicals that can be mutagens, and can cause negative immunological, reproductive, teratogenic, carcinogenic and neurological effects (Allen et al. 2022, SMEP 2022a; Barrowclough and Vivas 2021, UNEP 2016). At least 690 wildlife species, as well as coral reefs, are known to be affected by plastic debris.[5] Although the extent of economic and environmental impact of micro- and nano-plastics and chemical additives is still poorly understood, the ingestion of such particles by aquatic organisms, including fish species destined for human consumption and of commercial importance, has been documented in laboratory and field studies, and are expected to pose severe health hazards for marine ecosystems and the food web (SMEP 2022, OECD 2022; Barrowclough and Vivas, 2021).

5 Gall and Thompson, 2015 – reported by OECD, 2022

1.2 Actions underway to tackle plastic pollution

When seeking solutions to address plastic pollution a difference in the emphasis of efforts is important. Some actions might have a stronger focus on waste management and recycling technologies and capacities, which is commonly known as downstream. Other actions might be emphasizing the production and consumption phase, which is known as the upstream of a product life cycle. Current initiatives and policies tackling both sides of plastic products life cycle are critical to reducing GHG emissions because of the already high levels of plastic waste and GHG emissions. For example, it has been estimated that if instead of producing 14 million Mt of plastic packaging, only seven million Mt had been produced in 2006, 14.85 million Mt CO2e could have been avoided (CIEL, 2019). In this same report CIEL refers to another study conducted by USEPA, evaluating the climate change benefits of different waste management methods of 16 types of waste materials including three types of plastic (HDPE, LDPE, and Polyethylene terephthalate - PET), such as waste prevention, recycling, composting, incineration, and landfilling. The study shows that plastic waste prevention yields the biggest climate benefits, with 18 million Mt of CO2e reduction if waste generation dropped to 1990 levels and concludes that plastic substitutes, reuse, and recycling result in negative net GHG emissions, while combustion adds to the climate burden by increasing emissions (CIEL, 2019).

International initiatives on plastics are mostly framed in the pursuit of climate-resilient, pollution-free manufacturing and sustainable trade systems which are goals shared by both developing and developed nations. This is attested by countries' commitments to the Sustainable Development Goals, expressed in the Declaration of the United Nations Ocean Conference Our Ocean, Our Future: Call for Action (UNGA, 2017), recent United Nations Environment Assembly (UNEA) 5.2 resolutions (UNEA, 2022), the plastic waste Basel convention amendments, as well as the latest multilaterally defined UNCTAD mandate in the Bridgetown Covenant (UNCTAD, 2021d). These commitments recognize that countries can only rise to the challenges by working together and that holistic approaches are adopted. That is, embracing worldwide measures to Reduce, Reuse, Recycle, a global 3Rs initiative to "reduce waste and its generation, improving mechanisms for environmentally-sound waste management, disposal and recycling, and developing substitutes such as reusable or recyclable products, or products biodegradable under natural conditions" (UNCTAD, 2021a, p1.).

Apart from strong international efforts, there are regulatory measures on plastic pollution at the national level, all of which recognize the importance of acting on all plastic streams. At present, however, the most used measure has been to ban, tax or regulate certain single-use plastic objects, such as bags and disposable cutlery – as of 2021 more than 30 countries implemented this type of policy. All followed by policies such as extended producer responsibility which are being implemented in many developed nations and explored across developing countries, and particularly SIDS. In terms of initiatives, the trend is similar to what is observed at the global level: most funding is directed to downstream management of the plastic life cycle. Yet, some countries are exploring the development of labs for plastic substitutes or providing funds for the development of sustainable substitutes around natural fibres, especially for the textile and packaging industries, mulch films for food and agriculture and more biodegradable fishing nets (UNCTAD, 2021b; SMEP 2022).[6]

1.2.1 Upstream initiatives

Currently, there are limited efforts dedicated to "upstream" plastic reduction (Akenji et al., 2019). This despite the fact that developing substitutes to plastics, repurposing, reuse, are widely recommended in all global assessments (as well as at the regional and national levels). The production of plastics substitutes can favor the development of circular economies, are more inclusive of other forms of waste reducing

6 Through a competitive process SMEP has selected and financially supported high impact projects in program's targeted regions with practical plastics pollution mitigation solutions and focusing on demonstrating long term feasibility of solutions and potentials for uptake: https://smepprogramme.org/procurement/plastics-intervention/

costs and moving away from plastic production and consumption can greatly contribute to reducing GHG emissions. Especially GHG emissions resulting from virgin plastic and manufacturing of plastic, and ultimately reducing plastic waste management. Furthermore, some studies show that plastic waste prevention reduces GHG emissions the most and yields the biggest climate benefits (CIEL, 2019).

Leading up to the Stockholm+50 in June 2022, Chatham House's Environment and Society Programme held various consultations with different stakeholders on the key areas that needed a global coordination to advance the circular economy and emphasize upstream initiatives to produce and consume more sustainably. This process resulted in a set of recommendations, a so-called **Global roadmap for an inclusive circular economy** for Stockholm+50 (Schröder and Barrie, 2022) that would decisively and effectively address climate mitigation, enhance biodiversity gain, prevent pollution, and contribute to human development.

1.2.2 Midstream initiatives

Whereas upstream initiatives are crucial to addressing the problems at the source and thus design policy initiatives that not only emphasize but actively enable circular economy, midstream initiatives tackle plastics directly during the manufacturing phase.

At present, one key global initiative focusing on the midstream cycle is the **Sustainable Manufacturing and Environmental Pollution (SMEP) programme**, funded by the United Kingdom and implemented in partnership with UNCTAD until 2026. Alongside looking at plastics production, SMEP aims to reduce pollution at the manufacturing stage, rather than cleaning it up after release, thus being a concrete application of circularity principles (Hira et al., 2022). This program is currently being implemented in Africa, South Asia and in the Indo-Pacific region. Several case studies have already been produced on the possibility of changes in the manufacturing process, using upcycled plastics in the manufacturing stage, as well as the development of substitutes to plastics which would be non-toxic, biodegradable, erodable and conducive to the development of local productive capacities (SMEP, 2022).

UNCTAD's Oceans Economy and Fisheries Program is seeking to contribute to the shift from the use of plastic polymers materials, towards an increased supply and use of sustainable material substitutes such as natural fibres and biomass coming from agricultural wastes and algae that can have lower impacts on marine ecosystems (UNCTAD, 2021a). In accordance with SDG 14.1: "by 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution" as well as conclusions and recommendations on plastic litter and other ocean waste challenges made at the 4th United Nations Oceans Forum on Trade related aspects of SDG 14 (see Annex 1) (UNCTAD, 2022), which emphasized more support to plastic waste management, promoting "material substitutes to plastics via differentiated tax strategies, regulations, industrial policy, and green public procurement", and also the "further development of the HS System by the inclusion of special classifications relevant to material substitutes and alternatives to facilitate the adjustment of tariff schedules that will promote material substitutes and alternatives to plastics, and disincentivize trade in highly polluting, single-use plastics and hazardous plastic materials, control plastic waste trade, facilitate trade of services necessary for waste avoidance, management, and recycling; and support the development of export markets for material substitutes and alternatives, including high-quality recycled plastics".

Supported by the EURO Trust Fund financed by the European Union Regular Program of technical Cooperation, a program **SWITCH to circular economy value chains** led by the United Nations Industrial Development Organization (UNIDO) aims to support MSME (micro-, small, and medium sized) suppliers throughout selected value chains to adopt circular economy practices. UNIDO's project is focusing on European Union suppliers who need technical and financial assistance to switch to a circular economy model in sectors such as plastic packaging or textiles and garments.

The European Union agenda on combating the root causes of climate change, which includes reducing dramatic levels of plastic pollution is introducing the **Sustainable Products Initiative (SPI)**, which plans to make sustainable products the norm aiming “to make every aspect of the design, production, use and sale of products placed on the European Union market more environmentally-friendly and circular to deliver on the sustainability and climate objectives” (Euractive, 2022). The SPI will have profound consequences for both European Union and non-European Union upstream producers and suppliers who will need to adapt design and production methods to meet the increased requirements.

1.2.3 Downstream initiatives

Based on current information, the majority of funding and policy attention is directed towards initiatives associated with the downstream stage of the plastic life cycle (Portsmouth, 2023). These initiatives have made significant progress in becoming more effective, such as advancements in technologies for tracking end-of-life materials, designing products to reduce waste (e.g., by using less plastic or making recycling easier), as well as new recycling technologies and efforts to clean the oceans.

Design of policies and initiatives must not only consider overcoming plastic pollution and its damage at the national level but take due consideration of other countries to which plastic waste may be exported and countries that are most affected simply because of their geographical location or internal characteristics. Thus, lines of actions and funding – especially those that are being implemented in a concerted manner at the international level – must take into consideration differences among countries and their unique challenges. For example, SIDS are especially vulnerable to plastics-related dangers due to, among other reasons, limited recycling capacity and space to dispose of waste. For these economies support is required not only in terms of cleaning plastic waste but also in reducing dependence on fossil fuel generated polymers by developing emerging industries related to plastics substitutes. Support that must protect countries from environmental hazards, sustain main sources of livelihood, and create useful employment and economic development opportunities (Vivas and Barrowclough, 2021).

One of the more innovative downstream programs was developed by the International Atomic Energy Agency (IAEA) to support countries in their efforts to reduce plastic pollution by using nuclear science and technology. The program, **NUclear TEChnology for Controlling Plastic Pollution (NUTEC Plastics)**, is tackling plastics in their recycling phase using radiation technology and marine monitoring using isotopic tracing techniques to transform it into reusable resources (IAEA, 2021). The IAEA is supporting nuclear techniques research projects to i) monitor and assess marine plastic pollution, and ii) improve plastic waste recycling and upcycling.

2

STATE OF PLAY OF PLASTICS SUBSTITUTES SELECTED PRODUCT GROUPS

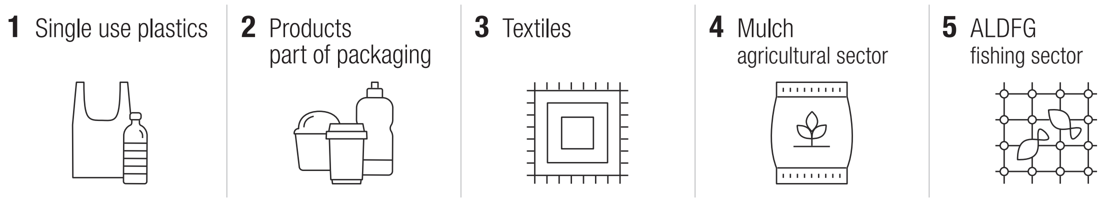
2. State of play of plastics substitutes: selected product groups

Nowadays, alternatives to plastic go beyond traditional materials such as glass, aluminum, paper, ceramics, and clay. New substitutes are constantly being developed and may provide an opportunity to start production of entirely new products based on pre-existing raw materials and with that to support more holistic or inclusive circular economies. For example, natural fibres (e.g., from coconut, palm), or organic waste such as crop residues and their associated products (e.g., bagasse and corn husks).

Undeniably, the move towards plastics substitutes requires innovation, new designs, and sustainable business models that encourage the lowest environmental impact. For example, business models for material substitutes should apply circular economy principles and avoid perpetuating a linear production and consumption pattern. This includes the entire value chain, from new materials (such as bagasse) to innovative technologies (such as “smart buoys” in the fishing industry) and new types of financing, such as blue financing instruments.[7]

Innovations need to take place across all plastic products for all types of industries, yet products discarded after one year or less of use make up 40 per cent of all plastic waste, and have become a serious concern for waste management everywhere (Hira et al. 2022). Such products are mostly found in product groups such as packaging, single use plastics, textiles, as well as the agricultural sector – mulch – and fishing sector – abandoned, lost, or discarded fishing gear (ALDFG). Furthermore, these are usually short-lived products that account for almost two-thirds of plastic waste; packaging waste alone constitutes 42 per cent of global plastic waste generated (OECD, 2022a).

Since the focus of the document is on plastic substitutes only, the section focuses only on potential substitutes to plastics clusters that contribute the most to plastic waste and put a significant pressure on countries’ waste management system capacities. The report concentrates on plastic substitutes that could potentially replace plastic products from the following clusters:



2.1 Identification of selected plastic substitutes First global assessment

At present increasing use or innovation on materials for polymers replacement are twofold:

1. **Plastics substitutes:** natural materials from mineral, plant, animal, marine or forestry origin that have similar properties to plastics. They do not include fossil fuel-based or synthetic polymers, bioplastics, and biodegradable plastics. Plastic substitutes should have a lower environmental impact along their life cycle (e.g., natural fibres, agricultural wastes, and other forms of biomass). Depending on the case, they should be biodegradable/compostable or erodable, and should be suitable for reuse, recycling, or sound waste disposal as defined by national, regional regulations or in internationally agreed definitions. They can include by-products. Plastic substitutes should not be hazardous for human, animal, or plant life.

7 https://blogs.worldbank.org/eastasiapacific/turning-tide-plastic-pollution-through-regional-collaboration-southeast-asia

2. **Plastic alternatives:** They can include bioplastics or biodegradable plastics. Bioplastics means bio-based polymers materials (e.g., by using vegetable fats and oils, corn starch, straw, woodchips, sawdust, and recycled food waste) and should be subject to material recycling. Biodegradable plastics refers to the end of life of plastics, indicating that they biodegrade in the natural environment, or that they can be composted. They can include their by-products. Plastic alternatives should have lower GHG lifecycle emissions when compared to plastics and not be hazardous for human, animal, or plant life.

Access to inputs, costs, quality, and environmental impact for both plastic substitutes and plastic alternatives are material, product and country specific. As mentioned in the Introduction, the focus of this paper is on **environmentally friendly plastic substitutes**. Therefore, any type of fossil fuels-based polymers and synthetic fibres as well as any form of plastic alternatives – such as bioplastics and biodegradable plastics – are excluded from the scope of this paper.

When analyzing environmental impact of plastic substitutes, a case-by-case scenario should be taken at every step of the value chain as the lowest-carbon material does not always have the highest utilization, compostability, recyclability, or use of recycled content (Feber, 2022). For example, the environmental impact of producing a certain raw material may differ across countries as some soils may require higher levels of fertilizers or even of pesticides. Furthermore, in certain countries, some raw materials may be at a disadvantage with respect to other materials due to past regulations that hampered the development of that industry or farming (SMEP, 2021b).

Figure 2. Plastic substitutes vs. plastic alternatives

PLASTIC SUBSTITUTES	PLASTIC ALTERNATIVES
Natural materials excluding fossil-based or synthetic polymers	Bioplastics or Biodegradable plastics (usually polymers materials produces from renewable biomass sources)
Mineral, plant, marine or animal origin	Vegetable fats and oils, corn starch, straw, wood-chips, sawdust, and recycled food waste
Similar properties of fossil fuel-based plastics	Should be subject to material recycling, biode-grade in the natural environment or that can be composted (end of life)
Should be biodegradable/compostable or erodable, and should be suitable for reuse, recycling, or sound waste disposal	
Should have lower environmental impact along their life cycle (e.g., natural fibres, agricultural wastes, and other forms of biomass)	
Can include by-products	Can include by-products
Should not be harzardous for human, animal or plant life	Should not be harzardous for human, animal or plant life
NON-PLASTICS	BETTER PLASTICS

Source: Vivas Eugui & Pacini (2022). Based on presentation on plastic substitutes HS codes, Life-cycle analysis and tariffs considerations. WTO Dialogue on Plastics.

Box 2. Fortuna Cools on key identifying criteria for environmentally sustainable and effective substitute materials

Technical characteristics: Performance sacrifices and performance improvements compared to status quo: air permeability, water permeability, water solubility, tensile strength, color fastness, UV fastness, end of life and circularity - can the material be recycled and/or reused, can economic value be captured at end of life, what are the costs associated with end of life, are these costs and processes different in different regions, countries, cities, etc., will the material be subject to existing or emerging Extended Producer Responsibility regimes, does the material break down naturally in 30, 90, or 365 days without extra enzymes or inputs, can the material enter municipal recycling, waste, or compost streams and in which locations, is the material backyard compostable in 30 days, which industry certifications does the material hold, etc.

Resilience characteristics and "hidden costs": The risks and benefits that are not directly captured in cost of goods and material performance: equipment and handling requirements by intermediate processors, including new machinery and new training required to work with substitutes, and frequency of machinery replacement and retraining ; failure rates and manufacturer tolerances; repairability–potential and cost; supply disruption risk, present day and 5-25 years forward–where are the materials produced, where can they be produced, who produces them, how many total locations can the materials theoretically be produced at commercial volumes and existing cost, and what will this look like moving forward; order lead times, at different volumes; upper and lower capacity constraints–max and min order quantities as well as ability, limits, and timeframe to scale up production, including pricing effects

Social and environmental characteristics: The way these materials affect people and places: local community engagement and familiarity with the materials–i.e., level of indigenous knowledge and indigenous support present, level of local political knowledge and support present; substitution–effect of new demand on land use and local economy; water use: is production of the material diverting or polluting potable or non-potable water; emissions: is production, use, and disposal of the material increasing or decreasing status quo CO2e emissions; industrial support: is material production creating new business opportunities or employment opportunities in places with high unemployment and/or limited advanced industrial opportunities?

Source: Contributions by Fortuna Cools (2022), Workshop on sustainable and effective substitutes and alternatives for plastics.

When introducing potential substitutes to plastic products from the selected five clusters – single use plastics, products part of packaging, textiles, mulch, ALDFG – several characteristics of their potential use should be considered:

- **Properties.** Plastic substitutes are constantly evolving to have similar physical properties to plastics. More and new plastic substitutes are emerging reaching the quality and features found in the equivalent plastic product (e.g., strength, flexibility, lightness, and malleability) at competitive cost. Additionally, new products based on material substitutes strive to have a lower environmental footprint than plastics. For example, the SMEP and Oceans programs in UNCTAD find abundant locally available substitute natural materials which are already being used to produce, for example, cloth bags, wooden cutlery, bagasse packaging, all of which have lower environmental footprints than plastic and most of which can be price competitive to plastics.
- **New business models.** An increasing number of plastic substitute products across all five clusters above, are using business models that promote sustainable circular economies and

nontraditional financing. Many are using crop residues or waste from other commodities that would usually be discarded, and laboratories that are developing these technologies start with their own seed funds or those from their associations, and are receiving funds from government programs – e.g., in the United Kingdom of Great Britain and Northern Ireland, Canada, Spain, or national not-for-profit organizations.

- **Food system.** Materials replacing plastics may be produced using inputs that could be otherwise used as food, for instance, corn. This concern can be even more relevant in the case of bioplastics (plastic alternative). This is a valid concern but limited to very few inputs when related to food products. New product development – especially plastics substitutes made of natural materials or biomass – are using waste or discarded biomass instead, e.g., husks, bagasse, banana and fish skin, etc. This is, however, a matter that must be tracked and given due consideration so to prevent negative impacts on food systems, and undesirable trade-offs between social, environmental or even economic impacts.

- **Negative externalities.** The production of some plastic substitutes may increase the generation of negative externalities – e.g., overuse of wood could lead to biodiversity loss, deforestation, water pollution and GHG emissions. A nature-based approach, using residues, such as the utilization of agricultural wastes can not only yield better results than plastics but will in general have fewer negative externalities. (See Box 1 for illustration on the case of bagasse, a channel to expand agricultural circularity).

- **Manufacturing capacity.** New natural substitutes are challenged to ramp up manufacturing capacity (SMEP 2022). While many products are available to replace plastics under the clusters identified, their production does not yet have the scale to provide a full substitution in local or international markets. Financing and timebound public support to meet product expectations or cope with the current or potential demand potential are among the most important stumbling blocks for developing or scaling-up substitutes for plastics. Additionally, the production of new substitutes can be country-specific depending on available biomass (e.g., availability of coconut, plant or wool fibres). Hence, some products may be adapted/tailored to scale up their reach at the national and/or international level depending on the case.

- **Organic waste opportunities.** New developments in substitutes can enable new methods to use and dispose of organic inputs. For example, extended use of plastic substitutes may need the development of compostable or treatment of organic wastes such as cotton and other natural based textiles. Most of these developments are taking place locally, yet these services and methods can be exported – e.g., at present the European Union and Food and Agriculture Organization (FAO) are providing training on production and disposal of organic mulch applications.

Box 3. An example of bagasse and copra/coconut fibre and their multiple applications

Bagasse is the fibrous part of a sugarcane stalk that's left over after extracting the juice and is considered a very important agricultural waste generated in small islands developing countries. Often this part of the sugarcane is discarded, incinerated, or used as a biomass source for sugar mills. Transforming sugarcane stalks into products is giving them a new life as raw materials. Because it is a non-edible byproduct of food production, this material is considered an extremely renewable resource. A variety of different products can be produced from bagasse, paper including packaging products, food packaging products (not least cups and bowls), textiles, biofuels, and even furniture. As a paper alternative, it can reduce wood usage by more than 52 per cent. It can replace the materials commonly used to make cardboard boxes, plywood, particleboard, and Styrofoam*. Bagasse also has important specific material benefits with respect to paper products in food packaging and

Box 3. (cont.) An example of bagasse and copra/coconut fibre and their multiple applications

Styrofoam such as tolerance to high temperatures (up to 200°F), grease and water resistance, durability, freezer and microwave safe, high insulation properties (internal temperature maintenance) and a longer shelf life (bagasse fibre is highly porous, it absorbs extra moisture and promotes breathability and a drier environment for the produce)**.

More generally, the benefits of bagasse can be grouped into three categories:

- **Renewable –** Around 1.2 billion tons of sugarcane are produced annually. From this, 100 million tons of bagasse are created each year. While some of this bagasse is burned as biofuel, much is discarded. Bagasse packaging production finds a new purpose for this agricultural byproduct that would otherwise have been disposed of, reducing waste and supporting farmers.
- **Biodegradable –** Although it is desirable that all products end up in local composting facilities, the reality is that a large share of it often does not. As bagasse is biodegradable, this can break down on its own over time (it can biodegrade within 30 to 90 days – one of the fastest) and, depending on the other inputs used in the product, it may not contaminate landfills or roads on which the bagasse-made product may end up.
- **Compostable –** In commercial composting facilities, post-consumer sugarcane products can break down in 60 days, bagasse can be composted entirely. When composted, bagasse turns into a nutrient-rich fertilizer of nitrogen, potassium, phosphorus, and calcium.

The UNCTAD supported project **"Fostering green exports through Voluntary Sustainability Standards (VSS)"** has developed an approach to assist developing countries in building their capacities to achieve sustainable growth through green exports. In the case of Vanuatu, UNCTAD, by using the VSS Assessment Toolkit, identified **copra/coconut** as a high-potential vegetable fibre sector for exports, which currently provides a livelihood for 80 per cent of the rural population. Focusing on crude coconut, virgin coconut oil, refined, bleached and deodorized oil for domestic tourist markets or high-value international markets, these were already organic thus with an enormous potential to scale and expand, but they faced restrictions when, for example, they needed certifications for their products. In 2019 UNCTAD supported Vanuatu's multi-stakeholder Coconut Summit that adopted an action plan in support of the implementation of the Vanuatu National Coconut Strategy 2016-2025, outlining actions needed to diversify their coconut-based exports from 4 products to 10 by the year 2025.

Source: Compiled by the authors, based on Sugarcane Fibre Packaging Guide.

Note: * Styrofoam is a known environmental hazard, and it presents some human health hazards, too. It takes 500 years or more to break down and consumes 30 per cent of the space in every landfill. Moreover, 20 per cent of Styrofoam doesn't end up in a landfill at all, instead polluting our oceans and littering our ground. Despite legislation in several states banning Styrofoam, its popularity persists. Its acceptance is dependent mostly on it being lightweight and cost effective and the fact that it can maintain internal temperature

**See: https://www.freshplaza.com/article/9098139/sugarcane-based-packaging-allows-breathability-and-creates-a-drier-environment/.

2.2 Toward an extended list of materials and product substitutes for plastics

At present a listing, or tracking, of all plastic substitutes that are being developed does not exist. This is a process in the making that can only be approached by continuously identifying substitutes that can have similar physical properties to fossil fuel-based plastics on a case-by-case basis. Similarly, information on each product cluster is scattered across different sources. The current state of the product cluster – the similarities across each product cluster – studied in this paper is presented in a nutshell below. The discussion is based on case studies and disclosed by novel enterprises. An **extended illustrative list of materials and product substitutes for plastics** in selected clusters is presented in Table 1; a list of corresponding HS codes is provided in Annex 2. Plastic substitutes discussed in this report could potentially replace plastic products from the following clusters:

Table 1. Illustrative list of plastic substitutes from selected clusters

Traditional substitutes	Textiles	Mulch	Packaging/ SUP	Textiles/pack/SUP
Aluminum	Areca leaves	Hay	Banana leaves and paper	Balsa wood
Ceramics	Banana leaves, stem, or fibres	Leather	Calabash hard shell	Bamboo
Clay	Bamboo fibres	Ray	Casein	Cellulose nanofibres
Cotton	Fruit peels	Straw	Cotton linters	Coconut husks
Glass	Beeswax-coated cloth	Seaweed film and fibres	Mushroom	Coir
Paper	Down	White clover	Rayon	Cork
Wood	Grape waste	Wood bark	Rice paper	Corn-based
Natural fibres and wools	Pineapple leaves	Woodchip	Seaweed and fruit peels films and paper	Cotton
	Tofu waste	Wool	Wood bark	Flax
	Silk			Fish skin or residues
	Various animal wools (alpaca, angora, cash-mere, sheep, etc.)			Hemp
				Jute
				Leather
				Microbial cellulose of mixed vegetables and bacteria
				Nettles
				Seaweed -brown and red algae by products
				Silk
				Sisal
				Sugarcane -bagasse
				Other plant materials
				Plant waste
				Wheat husks
				Wood pulp
				Woodchip

Source: Compiled by the authors.

2.2.1 Substitutes for synthetic textiles

Both synthetic and natural fibres, or a mix of both, are widely used by the textile, fashion, and internal home design industries worldwide, not only for clothing (short product life) but also for numerous home, office and industrial products such as furniture, carpets, curtains, cushions and geotextiles (long product life). The global market for textiles was estimated at $575 billion in 2022 with a compound annual growth rate of 8.3 per cent driven by changing consumer demands, online shopping, and fast fashion business models among others (ReportLinker, 2022).

Synthetic fibres are made of synthetic materials usually generated through chemical processes. Since the XIX century the textile industry has been creating a large variety of synthetic fibres derived from polymers such as polyester and nylon as they are cheaper, water and use resistant, and more easily mass-produced than most natural fibres. According to UNCTAD's Plastic Trade database (UNCTAD, 2022c), in 2020 the global exports of synthetic textiles were $169 billion in value and 61.5 million tons in volume.

Natural fibres are fibres that are made of natural materials that come from plants, animals, or even minerals. Plant-based natural fibres include cotton, linen, jute, hemp and sisal while animal-based natural fibres include silk and diverse wools. Natural fibres have the advantage of absorptive capacity, warmth, durability, biodegradability, and compostability. While many natural fibres have been around since neolithic times, this is perhaps the area where more existing and novel material substitutes and products are emerging such as areca leaves, banana leaves or stem, bamboo fibres, seaweed fibres, beeswax-coated cloth, grape waste, pineapple leaves (see box 3 for the case of banana, bamboo, and other fibres). A wider range of natural sources for fibre production could address issues such as price and versatility in functions, properties and use vis a vis synthetic material. Additionally, many natural fibres are highly fashionable in high-end value-added consumer products such as the case of alpaca, cashmere, camel, and natural silk products.

Box 4. Banana, bamboo, and other biomass-based fibres

Recently, due to consumer demand for more sustainable clothing, some enterprises have started research and product development of more sustainable natural fibres based on biomass and agricultural wastes. The share of biomass in so called "sustainable clothing" can vary from market to market, having some stricter criteria on minimum share biomass use, use of organic agricultural practices and no or low mix with synthetic inputs. One line of this trend is the direct use (and sometimes exclusive use) of **natural fibres from materials such as banana and bamboo fibres**. For example, **Bananatex®** a Philippine enterprise is the world's first durable, technical fabric made purely from the naturally grown Abacá banana plants and natural dyes. Cultivated in the Philippine highlands within a natural ecosystem of sustainable mixed agriculture and forestry, the plant is self-sufficient, requires no pesticides, fertilizer, or extra water. These qualities have allowed it to contribute to reforestation in areas once eroded due to monocultural palm plantations, whilst enhancing biodiversity and the economic prosperity of its farmers. Products by Bananatex include lightweight, standard, heavyweight fibres. In Switzerland, the enterprise Calida® has developed night clothing based on biomaterials fibres that are as sustainable as possible including bamboo, brown algae, and cellulose fibres (e.g., with Tencel® technology). It also uses, for certain clothing parts, 100 per cent recycled nylon obtained from old fishing nets.

Main advantages of these biomass-based fibres for textiles include: regulation of temperature, antibacterial, fast drying, low or no allergic reaction, biodegradable, and compostable. They can also assist in reducing biodiversity loss and provide for alternative livelihoods for communities at the lower levels of the value chain. Another example is **seaweed used by the Peruvian startup Biopencil®**

Box 4. (cont.) Banana, bamboo, and other biomass-based fibres

to revolutionize the way we write, and with that to protect the environment and create new job opportunities for fishing communities. "The world consumes 14 billion pencils every year. The New York Stock Exchange alone uses 2 million. While it takes a tree 10 to 14 years to be pencil-ready, it takes just two weeks for a trader to turn a pencil into sawdust (UNCTAD, 2018b)". To avoid cutting down trees, the company developed an environmentally friendly pencil out of algae cultivated and processed by local coastal communities.

Source: Compiled by the authors, based on https://www.bananatex.info/products_EN.html and https://www.calida.com/en-CH/cms/sustainability/materials/.

2.2.2 Agriculture: Mulch

Plastic mulch is widely used in the agricultural sector because of its many benefits, including moisture retention, weed control, and soil warming (FAO, 2021) – it is estimated that in the United States alone, farmers use around 1 billion pounds of plastic per year for crops, and about 143,300 tons of plastic mulch each year for vegetable production (EIP-AGRI, 2020; Velandia et al, 2020). This has a significant negative environmental impact as plastic debris remain in the farmers' fields: "every time a crop had been harvested and the soil was ploughed, many small pieces of the mulch film could be found mixed in with the soil" (EIP-AGRI, 2020).

Considering these challenges, and the importance of mulch for productivity and even climate adaptation, many substitutes and methods to use organic mulch have been developed. The type of mulch, or the technique, depends on the crop or plant (FAO, 2021). For instance, studies conducted on paper mulch show that it keeps soil consistently cooler than plastic mulch,[8] this type is hence usually recommended for cooler season crops. Other types of mulch include bio-based spray-on mulch,[9] such as those made from agricultural residues, are still being tested. Regarding organic mulches (such as straw, strip tilling, compost mulch, woodchips, wool mulch), studies indicate that these have the same benefits as plastic mulch, and they can be useful for some pest management, yet it may not be appropriate for all crops.

There are also new practices that can be used, such as living mulches (1) between rows (using, for example, white clover, winter rye), or (2) within rows (usually for field crops, but vegetable farmers are starting to use them) (Hoidal, 2021). These and other practices are being tested to, for example, provide solutions for accelerating the mulch degradation progress,[10] support Operational Groups in the framework of agricultural European Innovation Partnership (EIP-AGRI).[11]

Elizade University in Nigeria in collaboration with the Council for Scientific and Industrial Research (CSIR), South Africa are working on a project supported by the SMEP program to develop biodegradable mulch films (BDM) by using locally available natural polymers such as starch and other additives to customize biodegradation rates of mulches, to replace the current non-biodegradable Polyethylene (PE) mulch films (SMEP, 2022). This biodegradable mulch is specifically adapted to African climate crop cycles and has the potential to be expanded and scaled to many countries in Africa and South Asia, addressing a big challenge of removing microplastics from soil and aquatic systems, hence, improving human and ecological health.

8 Paper mulch benefits is in part due to the lighter color of plastic mulches, which tend to be tan to brown, whilst black paper mulches are now available in the market.

9 Which is the result of collaboration between entrepreneurs, for instance, researchers in Morris and AURI.

10 For example, the Spanish Operational Group project AColchados BioDegradables (GO-ACBD) available at https://ec.europa.eu/eip/agriculture/en/news-events/press-media/press-release/biodegradable-mulch-films-reduce-plastic-footprint/.

11 As outlined on the website https://ec.europa.eu/eip/agriculture/en/european-innovation-partnership-agricultural/.

Box 5. Seaweed-derived biopolymers to substitute plastic mulch

Seaweed has been known and consumed for centuries, but only recently with sufficient technology available and financial support for sustainable seaweed-derived bioactive compounds to be explored to substitute plastic packaging – including for food, cosmetic, pharmaceutical, nutraceutical industries and its use as mulch is being explored (Lomartire et al, 2022).

For example, **PlantSea** a biotech start-up based in the United Kingdom – is working on sustainable and affordable solutions to achieve 100 per cent biodegradable, soil-enriching products to address plastic waste in agriculture, including mulch films. The sustainable use of seaweed-derived biopolymers is increasingly being studied as part of the solution to replace plasticizers with biodegradable materials, and thus preserve the environment.

Source: Compiled by the authors.

2.2.3 Abandoned, lost, or discarded fishing gear (ALDFG)

ALDFG, also known as "ghost gear", includes fishing nets, traps, ropes, hooks, cables, and other commercial fishing gear, as well as plastic waste from aquaculture, which drift on the water's surface or clutter the ocean floor.[12] Most of this gear is made of diverse forms of polymers such as rayon, dacron, and nylon. It is estimated that nearly 2 per cent of all fishing gear, comprising 2,963 km2 of gillnets, 75,049 km2 of purse seine nets, 218 km2 of trawl nets, 739,583 km of longline mainlines, and more than 25 million pots and traps are lost to the ocean annually (Richardson et al. 2022). It has been estimated that ghost fishing gear can make up to 70 per cent of all macro-plastics in the ocean by weight (Jackson 2021).

ALDFG is also the deadliest form of marine debris affecting ocean fauna, often due to entanglement (OECD 2022) but also starvation (due to the false sense of satiety) (Link et al. 2019). Studies also find that an estimated 90 per cent of species caught in lost gear are of commercial value, and up to 30 per cent decline in some fish stocks is due to damage to important marine habitats from ghost gear. For example, a recent study found that removing derelict crab pots in the Chesapeake Bay yielded an additional $20 million in harvest for local fishermen in six years. If extended to a global level, the study showed that removing just 10 per cent of ghost gear could increase landings by close to 300,000 metric tons (Jackson 2021). At present, only a handful of initiatives are being implemented to respond and move away from the negative impacts of ghost gear. These include using plastic substitutes, recycled material, and technology to collect, or avoid losing, fishing gear. The main key issues for scaling up these innovations are their economic viability and the complexity – for some gear – to reach comparable physical properties as those made of plastic. Box 6 provides examples of initiatives and efforts to use plastic substitutes as well as plastic recycled material for fishing gear).

12 Gear loss occurs wherever fishing takes place, often due to rough weather, snags beneath the surface, and marine traffic accidentally running it over and cutting it loose. But it also happens from aquaculture for various reasons, such as low-level losses through routine farming operations, extreme weather events, and inadequate planning and management. Intentional discard can occur where other options are limited, oversight is sparse, and costs for proper disposal are high. https://www.globalseafood.org/advocate/the-hidden-cost-of-ghost-gear-lost-by-fishing-and-aquaculture/

Box 6. Targeted initiatives and efforts to use plastic substitutes as well as plastic recycled material for fishing gear

Seaweed has been known and consumed for centuries, but only recently with sufficient technology In recent years, innovations include products to prevent losing fishing gear (e.g., a semi-automated oyster growing system), technology that track and monitor all types of deployed gear (e.g., smart buoys that report the gear location to a mobile phone or website). There are also efforts for the development of gear made of plastic substitutes and alternatives. The latter includes all types of fishing gear made from natural and biodegradable material. For example, non-entangling biodegradable fish aggregate device (FAD) rafts made from bamboo, and balsa wood or other natural materials that degrade without causing impacts on the ecosystem, and FAD tails made from cotton ropes and canvas, manila hemp, sisal, and coconut fibre (Morgan, 2011; ISSF, 2019).

Regarding fishing nets, there are various R&D projects around nets produced with bio-based materials that can be water and weight resistant and at the same time biodegrade within a 1-to-2-year period. Materials for future prototypes may include natural silk and micro-algae. Projects with R&D lines for biobased materials include **Innovative Fishing Gear for Ocean (INDIGO)** and the Strategies of circular Economy and Advanced bio-based solutions to keep our Lands and seas alive from plastics contamination (SEALIVE). SMEP supported project GAIA Biomaterials in South Africa, Kenya and Tanzania also aims to replace polyethene with biodegradable and compostable fishing nets made in an innovative application of **Biodolomer®** (SMEP, 2022). Besides these initiatives, there are already a few companies producing and offering nets from recycled materials such as NetPlus® by Patagonia company, which is a material made from 100 per cent recycled discarded fishing nets collected from fishing communities in South America.

Source: Compiled by the authors, based on https://www.iss-foundation.org/fishery-goals-and-resources/our-best-practices-resources/non-entangling-and-biodegradable-fads-guide/, http://indigo-interregproject.eu/en/about-indigo/objectives/, https://sealive.eu/no-more-haunting-by-ghost-nets-bio-based-and-biodegradable-nets-could-be-the-solution/ and https://eu.patagonia.com/be/en/our-footprint/netplus-recycled-fishing-nets.html/.

2.2.4 Substitutes for packaging and single use plastics (SUPs)

Today plastic packaging and SUPs continue to be produced, used, and discarded at alarming rates. SUPs constitute approximately half of the global plastic waste generation, estimated to be at least 190 million tons annually. Packaging and SUPs waste disposal, already outpacing all existing waste processing methods due to the unprecedented amount produced, its complex multi-layer production, consumer use, and discarding, presents big challenges for recycling and disposal (CIEL, 2019). This is applicable to both developed and developing countries. As part of the response to this trend, numerous countries are applying bans on certain packaging and SUPs, particularly in SIDS; the results of this measure have been mixed, especially in terms of enforcement (Vivas and Barrowclough, 2021).

Some key challenges for existing or new substitutes of plastic packaging and SUPs are that these should not be hazardous for human, animal, or plant life, and should not aggravate waste streams that negatively impact the environment. For example, food packaging should not reduce shelf life of the products and hence increase food waste which may have a greater environmental impact than reducing the environmental impact of packaging (GIZ, 2021), and have a toll on food consumption. They should also be biodegradable, compostable, and recycled and avoid a mix with polymers and toxic additives.

The plastic packaging and SUPs cluster is perhaps where the greatest number of substitutes have been developed by the private sector in both developed and developing countries as a response to customer demands and an increasing shift in consumer behavior. For example, there are many innovative materials, packaging and single use items that are being produced from agricultural wastes, seaweed, and plant biomass. Box 6 provides an example on the use of seaweed and plant-based materials for producing food packaging and paper.

Box 7. NotPla and Bambusa: packaging material that disappears natural

NotPla® is an innovative company from the United Kingdom developing new and environmentally friendly packaging solutions. The company was one of five £1m winners of Prince William's Earthshot climate prize in 2022 for tackling one of the planet's greatest challenges, plastic pollution (Espiner, 2022). They make products from "Notpla", a material derived from seaweed and plants (fruit peels) that disappears naturally. Notpla is a non-chemically modified, polysaccharide*-based material. It is classified as a natural, organic substance by European Union law. Similar to a fruit peel, Notpla claims to generate "biodegradable" and "home-compostable" packing products. Product range includes non-plastic sauce sachets, pipes, films, paper, food containers, coated board to supply paper converters that are fully biodegradable.

Another example is **coconut fibre (coconut shells)** which is a well-known fibrous waste of coconuts. For now, the most used and valued part of the coconut is the white inner part of the coconut called copra, while the shell and the husk have not been widely used. But more and more developing countries around the equator that grow coconuts in abundance and are facing the environmental burdens of plastic pollution are looking into more sustainable materials. For example, in Jamaica, bamboo straws are successfully substituting plastic straws. Entrepreneurial efforts to introduce sustainable products to replace plastic, along with national policy and regulation changes that banned SUPs, proved a success and an example to learn from. For policy changes to succeed local businesses need to innovate and be ready to fill the gap when plastic products are banned. **BAMBUSA®** sold over 15,000 bamboo straws in only one year and with that replaced about 5 million plastic straws and, according to the company, each bamboo straw replaces on average 360 plastic straws. Now, the company has other natural products in the making such as bowls and candles made from discarded coconut shells (UNCTAD, 2021e).

Source: Compiled by the authors, based on https://www.notpla.com/ and https://unctad.org/news/jamaican-start-shows-potential-plastics-substitutes/.

Note: *Polysaccharides are major classes of biomolecules. They are long chains of carbohydrate molecules, composed of several smaller monosaccharides. These complex bio-macromolecules function as an important source of energy in animal cells and form a structural component of a plant cell.

2.3 Life cycle analysis of plastic substitutes

Whilst natural-based materials and products may be ideal substitutes to plastics, policymakers need to assess the viability of pursuing these transitions. The advantages and positive properties of each potential substitute need to be analyzed case by case against sound product life-cycle criteria, its lifespan (how many times it is used), and disposal capacities in each country. Various examples of potential material substitutes, as listed in Table 1, have already been assessed against SUPs life cycle in selected countries in Sub-Saharan Africa and Southeast Asia (UNCTAD 2021b). These data support the claims that the most suitable substitute to plastic may not be equally applied to all fossil fuel-based plastics with similar properties, or across countries, and not even within sectors but it depends on a local context in terms of availability of materials, consumers' behavior, country's capacity to process waste, and substitute's reusability. There are discussions about LCA and geopolitical risks related to materials (such as abaca fibres) that are exclusively available or produced by certain actors in locations that are impacted by armed or non-armed violence as these circumstances can cause disruptions along the value chains (Fortuna Cools, 2022).

When phasing out plastics, a detailed assessment about the type of substitutes, their availability, potential constraints, external costs and benefits compared with the plastic product, essentially comparing the full lifecycle costs and benefits of both plastic products and their substitutes is necessary (World Bank, 2022). In a recent study by McKinsey (2022) authors analyzed environmental benefits of plastics in comparison to traditional plastic substitutes (e.g., glass, aluminium, etc.) and found that plastics have a lower total GHG impact than substitutes considering the product's entire life cycle, which spans from raw material acquisition throughout the end-of-life and includes its value-chain impact. That said, as pointed out by SMEP (2022), World Bank (2022) and UNEP (2021), LCA analyses on plastic substitutes need to recognize the importance of going beyond GHG emissions. Assessments of litter and health impacts are not yet well accounted for in LCA studies and should be carefully considered. There are also information gaps relating to long-term impacts on ecosystems and health, such as the issue of microplastics. Social aspects as well as gender analysis also need careful consideration (UNEP, 2021, p.5).

Based on data collected for the Sustainable Manufacturing and Environmental Pollution (SMEP) Programme – supported by UNEP and the World Bank conclusions - about plastic substitutes primarily for the SUPs cluster, the following points can be drawn from the LCA conducted on potential plastic substitutes and substitute materials that were selected based on their local availability by the SMEP study:

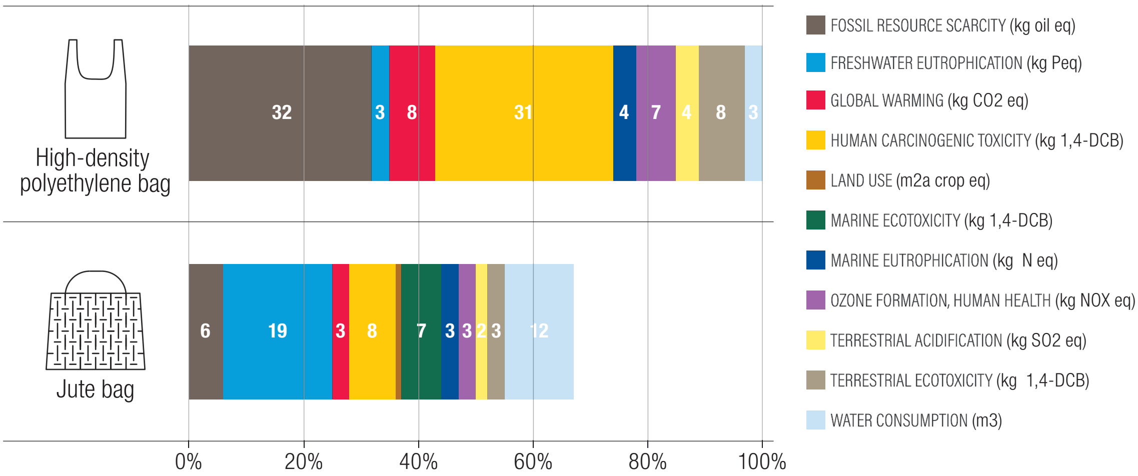
- Location matters, which essentially means the country in which the LCA is performed, as it has unique characteristics regarding: a) energy matrix affects environmental performance and proves that fossil-based sources have a greater negative impact in production, consumption, and disposal phases than renewable sources,[13] b) waste management systems, and c) consumption and post-consumption behavior affect the environmental performance.
- The agricultural phase can cause impacts on land use, eutrophication and water consumption and can make the substitutes based on natural fibres from dedicated crops more environmentally damaging than SUPs in some cases.
- Ranking on suitability of certain products is challenging, whether that be for plastics, alternatives to plastic or plastic substitutes as it depends on what environmental aspects are given higher priority.
- The mass of the substitute product is an important factor to be considered because transport and end-of-life can be highly impacted by this factor, which can even make the substitutes worse than SUPs in some cases.
- End-of-life system adequacy is crucial, and if not in place not even plastic substitutes can offset environmental damage.
- Reuse makes the difference for environmental performance for all reviewed materials, and it can offset a higher environmental impact of substitutes to plastic in comparison to plastics, when substitutes are reused. To support these claims, Figure 3 below illustrates the significance of reusability of a plastic substitute.

For the case in Figure 3 (below) jute bags were chosen as substitutes considering that the single yarn of jute or other textile bast fibres (HS code 530710) are largely available being among the top 12 primary products produced from crops, while also being the second product in terms of exported quantity in Bangladesh and jute is the twelfth primary product from crops in terms of produced quantity (SMEP, 2021b). The scenario (methodology described in Box 8 below) was run under the assumption that both bags carry 5kg of items for three years shopping from a supermarket to home estimating 156 shopping trips in total. The HDPE and jute bag both are of similar size, with two handles to carry, although the jute bag is heavier (360g/m2 of jute fabric plus 15g/m of cotton webbing) in comparison with 4.4g for the HDPE bag. The HDPE bag performs worse than the jute bag, mainly due to the impacts on fossil resource scarcity and human carcinogenic toxicity. The jute bag, considering it is reused 156 times over 3 years,

13 See annex I, at the SMEP Trade and Pollution Dashboard under Reports at http://bit.ly/SMEP_UNCTAD/.

performs better than the single-use HDPE bag, even though there are significant relevant impacts related to the agricultural stage, especially marine ecotoxicity use and freshwater eutrophication.

Figure 3. Normalized process-based LCA for Bangladesh



Source: SMEP Dashboard (2023).

Box 8. Life-Cycle Assessment Methodologies used for sector-based LCA and for product-based LCA

For the part related to environmental burdens related to trade and pollution exported through manufacturing (SMEP/UNCTAD 2021c), the input-output LCA (IO-LCA) was used. It recently emerged as a new approach to LCA and uses Environmentally Extended Input-Output Analysis (EEIOA) tables as inventory data, following the impact assessment and interpretation phases. EXIOBASE was the chosen supporting database, as a global, detailed Multi-regional Environmentally Extended database. The analysis used a cradle-to-grave system boundary. Impact assessment was performed using ReCiPe and a set of indicators that includes the indicated categories for IO-LCAs performed using EXIOBASE.

For the set of LCA data on substitutes to plastic products (SMEP, 2022b), process based LCA was performed to assess the potential environmental and health impacts associated with some of the main exported products (in terms of quantity) for the selected manufacturing sectors, in the case study countries. With more detailed inventories, the aim was to better understand the main issues and the areas to be prioritized for action. Standard databases, namely ecoinvent (Wernet et al., 2016) and World Food LCA Database (Nemecek et al., 2014) were used, supported by technical literature when necessary. Ecoinvent is a renowned international inventory database founded by Swiss institutes which provides process data for products in many areas such as energy supply, agriculture, transport, chemical, construction materials, and waste treatment. The World Food LCA Database (WFLDB) is a comprehensive, international life cycle inventory database for agri-food products resulting from an initiative led by Quantis, a sustainability consulting group, in partnership with leaders in the agri-food sector. A cradle-to-grave system boundary was adopted. Impact assessment was performed using ReCiPe and a set of indicators that includes the indicated categories for process based LCAs performed using ecoinvent as a database.

2.4 Economic viability of plastic substitutes

The numbers of plastic production and its end-of-life management are far from being either aligned or sustainable. In 2019, "the OECD economies generated almost half of all plastic waste: the United States accounts for 21%, OECD Europe 19% and the remaining OECD countries 9%. Outside the OECD, China produces 19% of global plastic waste, India 5% and the rest of the world 27%. In terms of waste per capita, there are stark differences across the world. The United States had the largest plastic waste footprint in 2019, at 221 kg per capita, while OECD Europe had 114 kg plastic waste per capita. Japan and Korea's plastic waste generation is relatively low for industrialized countries, averaging 69 kg per capita. Finally, China generated 47 kg of plastic waste per inhabitant in 2019, while India generated only 14 kg per inhabitant"[14] (OECD, 2022). These numbers are indeed high when considering, for example, that **in the United States, out of all plastic waste generated in 2021, only 5 per cent to 6 per cent was recycled** (WEF, 2022b). Furthermore, plastics in general have a limited, if at all, recycling potential, whereas on the other hand some traditional plastic substitutes like aluminium or glass have indefinite recyclability and yet in the United States only about one third of glass bottles get recycled. These numbers speak to the insufficiency of plastic and other waste management systems that comes at high environmental, as well as economic cost and both are relevant in a discussion of substituting plastics for a non-plastic substitute material.

Box 9. Revealed Comparative Advantage (RCA)

The Atlas of Economic Complexity: Mapping Paths to Prosperity, an economics book (Hausmann et al, 2013a), which attempts to measure productive knowledge each country has, highlighted two websites that provide interactive visualizations of trade related data. The Observatory of Economic Complexity (Simoes and Hidalgo, 2011), a tool that visualizes data about countries' economic activities and the products each country imports and exports and Harvard's Center for International Development Atlas of Economic Complexity (Hausmann et al, 2013b), which maps global trade, industrial capabilities, and economic dynamics for the world. According to the latter, the RCA is an estimation of whether a country is an exporter of a product, based on the so-called "relative advantage" or "disadvantage" it has in the export of a certain good.

To estimate if a country has "revealed comparative advantage" in a product in a specific year, the analysis compares the actual exports of a product in a given year and compares that value to its "fair share". Hypothetically, if all countries in the world were the same, each would have a homogeneous participation in the global market-share of each of the products; from this hypothetical reference of "fair distribution", for those countries that have participation beyond what would be their homogeneous share, it is assumed that they have a revealed comparative advantage in this product. Therefore, when the RCA is greater than 1 it means a comparative advantage exists.

It is important to state that this is a static revealed advantage measure, the estimation is made for a product, exported by a country, in a specific year. That does not mean that new development policies cannot dynamically change the capacity of countries to acquire productive capacity and finally become able to export different products with greater RCA, building up comparative advantages and moving forward on a development path. In the green growth context, a green product space methodology (Hamway, Pacini, and Assunção, 2013) was suggested for policymakers to identify high-potential sectors and green products for their country to produce and export and thus spur green growth.

14 Data based on the OECD Global Plastics Outlook Database.

Plastic substitutes should, by definition, not overwhelm waste management capacity the way plastics do. However, substitutes and their end-of-life impact need to be studied in order to develop industries to address material recovery and recycling capacities for a selected substitute material (UNCTAD, 2021b). From the data available, along with the combination of the two available indicators – **revealed comparative advantage (RCA) and recovery/recycling rate - the economic viability of material substitutes** can be observed. Due to its features described in Box 9, RCA can be a useful proxy of existing productive capacities of a country to supply alternative materials. Additionally, the recovery or recycling rate for a specific material waste stream provides an indication of the effectiveness of the allocated infrastructure and capital for reuse and recycling in a particular market. In other words, RCA indexes can suggest how competitive a country is in each material or product, and recovery/recycle rates can serve as an indicator of the efficiency of downstream management for the same material. Hence, **the ideal substitute to plastics should ideally be both competitive and efficient in downstream management of wastes where it is adopted**.

Figure 4 indicates that, among top exporters, most of the plastic products selected are exported with an RCA[15] higher than 1, which means top exporters of plastics are usually also competitive or, in other words, possess relatively good productive capacities. The area indicated in grey in Figure 4 shows that, although these top exporters possess relatively well-developed productive capacities, they are doing so with a recovery/recycling rate below 60 per cent. This analysis of exporters and recycling rates with the RCA in perspective suggests that these countries could, with relatively low incentives, adapt and quickly achieve better recovery/recycling rates on these products. So, the grey area shows which products (exported by these top exporters) could be moved to the preferred blue area, therefore reaching a higher than 60 per cent recovery/recycling rate where RCA is already high, to therefore become the most suitable substitutes for plastics. Policies to improve the RCA while improving recovery/recycling rate could also be suggested, but results would require longer term and more substantive policies to combine better recycling rates and more complex productive capacities.

An UNCTAD report indicates that in terms of Revealed Comparative Advantage (RCA) and levels of recyclability aluminium does quite well as a substitute for plastics in these regions, while various forms of papers, crops, and plant residues do even better in terms of recovery and compostability rates (UNCTAD, 2021c). For example, a high recovery/recyclability rate for aluminium is probably linked to the intrinsic value of the material and to the fact that aluminium was one of the first materials to be recycled jointly with glass and certain plastics. To facilitate transitions away from plastic, policymakers, and relevant stakeholders should consider improvements in resource recovery, recycling, and industrial substitutes development in their agenda. If such mid-and downstream improvements are pursued, materials such as aluminium, crop residues, and glass could more easily displace plastics, resulting in more sustainable material transitions, particularly in developing countries." (UNCTAD, 2021b, p6.).

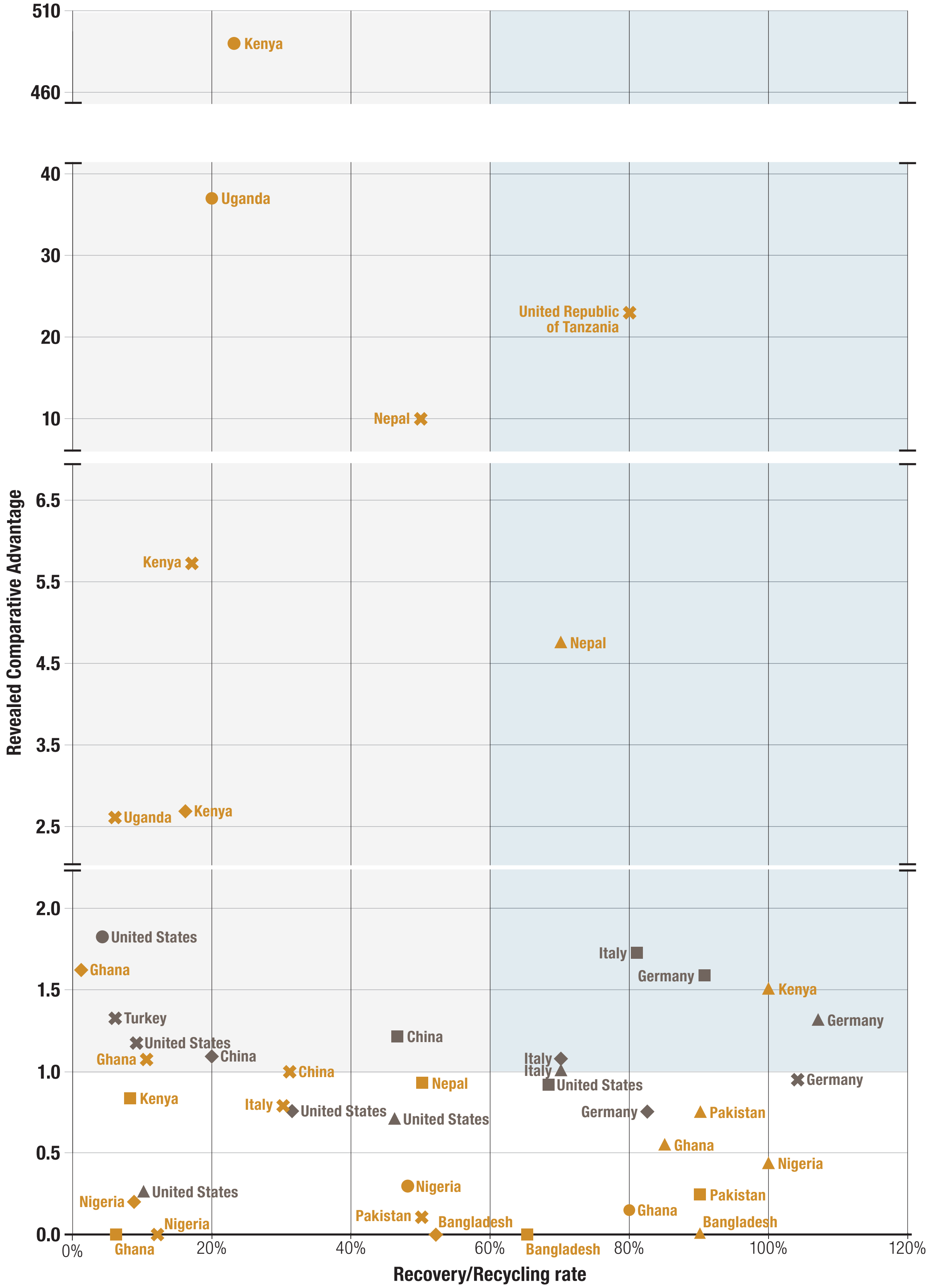
Figure 4. Selected exporters by their RCA and recovery/recycling rate per product group

KEY	PRODUCTS		COUNTRIES	INDICATED AREA
	▲ ALUMINIUM	■ PAPER	RCA TOP EXPORTERS	RECOVERY/RECYCLING RATE BELOW 60%
	● CROP RESIDUE	✖ PLASTIC	RCA SELECTED DEVELOPING COUNTRIES	IDEAL SUBSTITUTE FOR PLASTIC
	◆ GLASS			

Source: RCA based on UN COMTRADE data (2019). Recovery/recycling rates based on UNCTAD (2021c) and literature review.

15 Review Box 8 for a simplified definition of Revealed Comparative Advantage (RCA).

Figure 4. (cont.) Selected exporters by their RCA and recovery/recycling rate per product group



3

PURSUING PLASTICS SUBSTITUTES THROUGH A TRADE LENS

3. Pursuing plastics substitutes through a trade lens

Inputs required to produce plastic substitutes or final products, that could be used instead of plastic products, may be supplied locally, or may come from international markets via imports. Similarly, countries that have the raw material or final products made of plastic substitutes can find niche markets outside their borders, creating opportunities for exports.

Given the internationalization of plastics, and that some plastic substitutes – raw materials or final products – are already being traded across borders, this section looks at substitutes to plastics through a trade lens. To assess current trends of plastic substitutes trade flows, as well as the policies underpinning substitutes, the paper uses the Harmonized Commodity Description and Coding System (HS) codes for the plastic substitutes discussed in Section 2. The HS codes are ideal for assessing trade policies because these offer an internationally shared approach to classifying products, it is a tool for tracking and measuring trade flows across borders (applied by virtually all countries to clear commodities that enter or cross their borders), used for the implementation and negotiation of trade policies, and have the highest level of product disaggregation.

The HS codes have many benefits, but also some limitations that must be considered for the assessment of trade trends and trade policies, as well as for policy actions that governments can take to enhance monitoring – i.e., drafting and assessing evidence-based policies affecting supply and demand for plastic substitutes. This section, therefore, starts with a brief discussion on HS codes. This is followed by the analysis of key trade patterns and material recovery of substitutes to plastic, and the market access policies that countries are implementing on the identified HS codes.

3.1 Benefits and challenges of using HS codes

The HS classifies goods according to their nature (e.g., agricultural or manufactured product), the way they are presented for sale (for example, medicine can be classified according to whether doses are supplied as tablets or ampoules), their final use (e.g., juices are classified by the type of fruit, not by the type of packaging), and whether or not they are intended for retail sale. The classification tries to strike a balance between the level of disaggregation that exists in the marketplace by sector or industry; the ability of customs authorities to use the classifications in practice in their work; and the need for a logical structure that is supported by well-defined rules to achieve uniform classification. Additional criteria or considerations are applied to sub-headings for certain products in response to evolving market and technological developments (e.g., the emergence of lightbulbs using LED technology) or changes in the kinds of goods that are traded internationally.

Because of the wide array of products that exist, and of how the HS is constructed, finding the HS code of a product is not always a clear-cut task. In fact, this is a task that is sometimes also problematic for customs officers. The lack of clarity about which HS code applies to which product – especially new products – means that sometimes customs officials from different countries may register the same product under different HS codes.

Moreover, a commonly recognized hurdle of the HS, for the analysis of traded goods, is its level of aggregation. This problem can be resolved to a certain extent by using the national tariff line with a higher level of disaggregation. Almost all countries create subcategories of existing international classifications.

However, this is not possible at the global level since tariff line codes can differ across countries. To cope with this limitation, yet include HS codes that contain plastics substitutes that are free from plastics and avoid overestimating the value of these plastics substitutes, the following rules were followed:

- Disaggregated HS codes that didn't contain paint or any other plastic substance, were preferred over HS codes that contain such kind of plastic whenever possible.

- Within the category of fishing gear products (that is, products part of ALDFG), there are three HS codes for products made of natural material: fishing nets (one HS code) and fishing cable & ropes (two HS codes). Under ALDFG "other" group four HS codes were identified for fishing products made of natural material but also plastic. Because of the relevance of all products part of ALDFG, all HS codes relevant for fishing gear that may be made of plastic substitutes were kept so to, at least, assess the trade policies that underpin such products.
- Using the same HS code when the HS did not have a specific HS code for each of the identified raw materials or products; for example: Areca leaves/Banana leaves or stem/Pineapple leaves are all part of HS code 140190. Some raw materials – e.g., vegetables or crops byproducts, or final products were included under a same HS code

Based on the above, a **total of 282 HS codes were identified.** A broad array of substitutes to plastic is covered under HS Chapter 44 (Wood and articles of wood), 47 (Pulp of wood or other fibrous cellulosic material), 48 (Paper and paperboard), 51 (Wool, fine or coarse animal hair, yarn and woven fabric), 53 (Vegetable textile fibres; paper yarn and woven fabrics of paper yarn), and 76 (aluminium and articles thereof). A total of 29 HS codes were identified as HS codes containing agricultural commodities (among which waste and byproducts) and products of the food industry, i.e., codes from HS Chapters 4 to 23. Table 2 provides a summary of the HS codes identified (family of products with many potential substitutes, more than 15, are in bold), and Annex 2 provides the full list of HS codes.

Table 2. Summary of HS codes identified for plastic substitutes per HS code chapter*

HS Chapter	Description	6-digit HS Codes
04	Dairy produce; birds' eggs; natural honey; edible products of animal origin, n.e.c.	1
05	Animal originated products; not elsewhere specified or included	3
07	Vegetables and certain roots and tubers; edible	8
08	Fruit and nuts, edible; peel of citrus fruit or melons	2
11	Products of the milling industry; malt; starches; inulin; wheat gluten	3
12	Oil seeds and oleaginous fruits, industrial or medicinal plants; straw and fodder	7
13	Lac; gums, resins and other vegetable saps and extract	4
14	Vegetable plaiting materials; vegetable products not elsewhere specified or included	4
15	Vegetable waxes (other than triglycerides); whether or not refined**	1
17	Sugars and sugar confectionery	2
20	Preparations of vegetables, fruit, nuts or other parts of plants	1
23	Food industries, residues and wastes thereof; prepared animal fodder	4
28	Inorganic chemicals; organic and inorganic compounds of precious metals	2
29	Organic chemicals	2

Source: The HS 2022 version was used to identify the codes.

Note: * With a count of 6-digit HS codes identified per HS chapter, totaling 282 HS codes.

Table 2. (cont.) Summary of HS codes identified for plastic substitutes per HS code chapter*

HS Chapter	Description	6-digit HS Codes
32	Glass; glass frit and other glass, in the form of powder, granules or flakes*	1
39	Cellulose; Natural polymers	5
40	Rubber	4
41	Raw hides and skins (other than furskins) and leather	12
42	Articles of leather, articles of animal gut (other than silkworm gut)	1
44	**Wood and articles of wood; wood charcoal**	**43**
45	Cork and articles of cork	7
46	Manufactures of straw, esparto or other plaiting materials; basketware	8
47	**Pulp of wood or other fibrous cellulosic material; recovered (waste and scrap)**	**17**
48	**Paper and paperboard; articles of paper pulp, of paper or paperboard**	**31**
50	Silk	10
51	**Wool, fine or coarse animal hair; horsehair yarn and woven fabric**	**25**
52	Cotton	3
53	**Vegetable textile fibres; paper yarn and woven fabrics of paper yarn**	**19**
54	Man-made filaments; strip and the like of man-made textile materials	4
56	Wadding, felt and nonwovens, special yarns; twine, cordage, ropes and cables	4
57	Carpets and other textile floor coverings	1
63	Textiles, made up articles; sets; worn clothing and worn textile articles; rags	2
67	Feathers and down, prepared; and articles made of feather or of down	1
68	Stone, plaster, cement, asbestos, mica or similar materials; articles thereof	1
69	Ceramic products	4
70	Glass and glassware	9
76	**Aluminium and articles thereof**	**17**
94	Furniture, not elsewhere specified or included	4
95	Toys, games and spors requisites, parts and accessories thereof	4
96	Miscellaneous manufactured articles	1

Source: The HS 2022 version was used to identify the codes.
Note: * With a count of 6-digit HS codes identified per HS chapter, totaling 282 HS codes.

Table 3 below offers an insight into new materials that could replace or even improve functionality of plastics or usage of plastic materials during product production. Since these potential plastic substitutes do not have an applicable HS code they are presented as an example of the HS codes limitations this paper encountered. This fact underlines the importance of the revision of the HS system, along with a consideration that some of the functions performed by current products will likely be performed as a service model instead.

Table 3. Potential plastic substitutes products for which an HS code could not be identified

Plastic substitute	Composition	Application	Advantages	Limitations
Vegetable Tanned Leather*	Bark, berries, roots, and leaves used in place of heavy metals preserve the leather, produce a long-lasting, adaptable, and supple material, provides safer working conditions, less dangerous waste, and a leather product that is biodegradable at the end of its life.	Used in fashion industry to replace products made with animal leather.	Leather to be upcycled so using only the unsustainable material that's already done its damage.	Long to biodegrade.
Squid's parts in Biomimicry**	Pennsylvania State University have discovered that a protein in squid ring teeth (SRT) - in the suckers in their tentacles - can be engineered in a lab to be of wider use.	Can be used in cosmetics, building industry, textile industry to create protective garments and in the medical field due to its natural biocompatibility and biodegradability.	Coating a fibre in the protein makes it much more durable. The protein also has self-healing properties. SRT proteins are cheaply and easily produced from renewable resources without depleting squid population.	More development is needed to become widely available.
Platinum silicone***	Platinum silicone only uses platinum (precious metal) as a catalyzer. It doesn't contain bisphenol, thus no health or environmental risks, no waste, and does not change the taste of food.	Production of pharmaceutical, biotechnology, injectables, and food and beverage products, also manufacturing of automotive products, electronics, clothing and footwear.	High tear and tensile strength, very low shrinkage, fine detail reproduction, and an extensive range of hardness, withstands temperature extremes, repels water and germs, versatility.	High tear and tensile strength, very low shrinkage, fine detail reproduction, and an extensive range of hardness, withstands temperature extremes, repels water and germs, versatility.

Source: Compiled by the authors.

Notes: *Resources for Vegetable Tanned Leather were compiled by authors. More information available at the following websites: https://www.sustainablejungle.com/sustainable-fashion/sustainable-fabrics/#item-9/, and https://www.sustainablejungle.com/sustainable-fashion/sustainable-fabrics/#item-28/.

**Resources for Squid's parts in biomimicry were compiled by authors. More information available at the following websites https://www.bbcearth.com/news/six-fashion-materials-that-could-help-save-the-planet and https://www.alcimed.com/en/alcim-articles/biomimicry-and-smart-materials-how-did-squid-inspire-self-repairing-materials-in-wet-environments/.

***Resources for Platinum silicone were compiled by authors. More information available at the following websites https://www.thehomeshoppe.com.sg/pages/about-platinum-silicone/ and https://www.simtec-silicone.com/blogs/platinum-cured-silicone-its-role-and-uses-in-todays-custom-manufacturing-processes/.

Table 3. (cont.) Potential plastic substitutes products for which an HS code could not be identified

Plastic substitute	Composition	Application	Advantages	Limitations
Moulded dinner plates	Sugar cane.	Catering.	Biodegradable, renewable.	Upstream ecotoxicities.
Biodegradable bag	Vegetable starch, glycerin and poly (vinyl alcohol).	General goods transportation.	Biodegradable, renewable.	Upstream ecotoxicities, not conducive of systems change.
Diverse forms of packaging	Banana or areca leaves.	Physical shielding and transportation.	Biodegradable, renewable.	The closest subheading match appears to be HS 1401.90 ("Other vegetable materials of a kind used primarily for plaiting" – for example, bamboos, rattans, reeds, rushes, osier, raffia, cleaned, bleached or dyed cereal straw, and lime bark).
Hemp bags	Hemp.	Physical shielding and transportation.	Biodegradable, renewable.	The closest subheading match appears to be HS 6305.90 ("Sacks and bags, of a kind used for the packing of goods; Of other textile materials").
Algae (material)	Algae biomass source, alginate natural polymer.	Various uses.	Low carbon footprint.	Limited production scales.
Crustacean shells	Crustaceans' biomass source.	Various uses.	Low carbon footprint, connects with creative industries.	Limited production scales.
Vivomer (proprietary)	Microbes found in soil and oceans.	Various uses, especially containers.	Fast biodegradation	Limited production scales.

Plastic substitute proposed by WCO. (Moulded dinner plates, Biodegradable bag)

Plastic substitute proposed by TESS. (Algae, Crustacean shells, Vivomer)

Source: Compiled by the authors.

3.2 Taking stock of the key trade patterns of substitutes to plastic

Based on the 282 HS codes for plastic substitutes the total global exports in 2019 is $388 billion[16] of which two thirds represent export of raw materials ($258 billion), $125 billion is the exported value of products, and $4 billion of ALDFG. Even though in terms of total global exports, the share of plastic substitutes (2

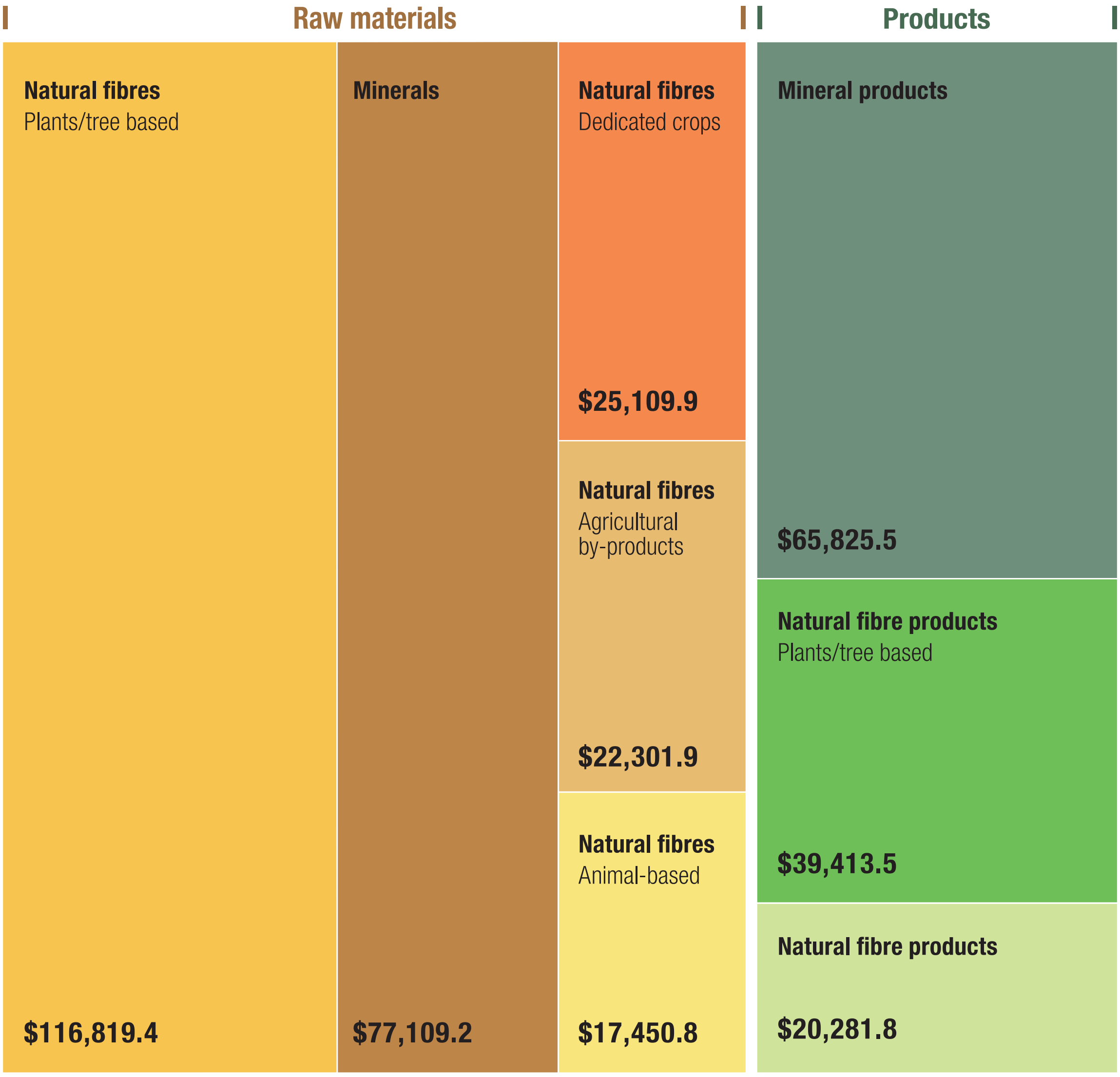
16 As discussed in the Section 2, due to HS codes limitations, several HS codes for plastic substitutes include products, or raw materials, that are used for other purposes than to replace plastics, while some products may not be included because of lack of HS code. The values herewith must be therefore analyzed with caution.

per cent share) is less than that of plastics (5 per cent share of global exports) these are nevertheless significant numbers that can be scaled up with adequate policy support and incentives.

In Figure 5, trade data show raw materials as the most traded in respect to final produce, which suggests that the development of substitutes to plastics is taking place outside the source countries. A fact that is a missed opportunity (or an opportunity to grasp) for raw material exporting countries, but also for partnerships between countries – regionally and internationally. Transitioning towards plastic reduction does not need to be at the expense of today's plastics exporters.

The export data (Figure 5) also reveals that Natural Fibres - Plant/Tree-based - constitute the lion's share of raw material exports (45 per cent of total exports of raw materials), especially Wood Pulp (29 per cent of raw materials) and Wood chips (26 per cent of raw materials), which are increasingly being used in packaging, single use plastics and mulch, in addition to being part of the traditional source for textiles and other products made of plastics.

Figure 5. **Plastic substitutes share of exports by HS category and type in Mn$ (2020)**



Source: Compiled by authors, based on COMTRADE data 2020 and HS 2022 codes.

Note: Mineral-based materials are considered aluminum, ceramics, and glass. Mineral products refer to products made of these materials.

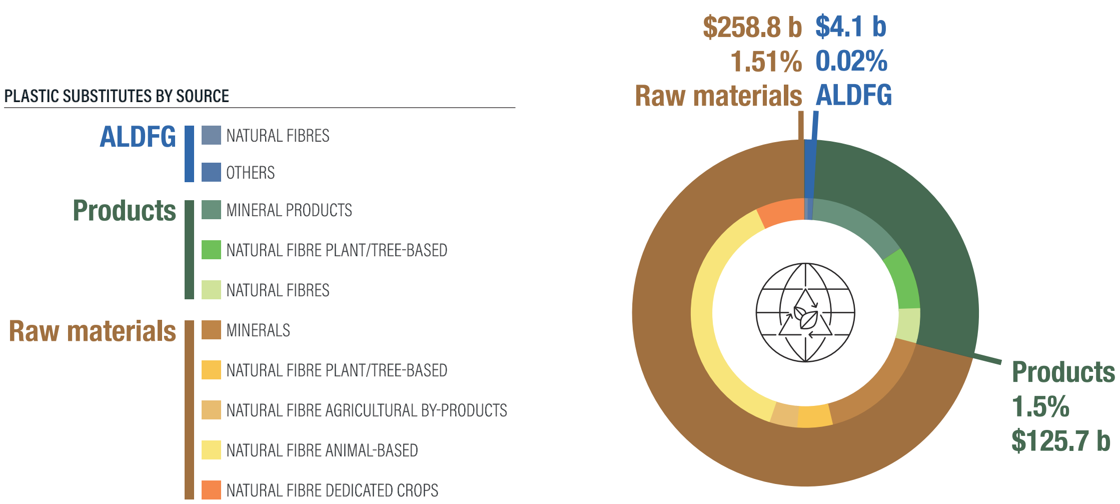
The global export of plastic substitutes, as represented by their HS codes, currently represents a low overall percentage of world trade. The most commonly traded substitutes are those that have been traditionally used to replace plastic, such as aluminum (0.69 per cent of world trade), cotton (0.08 per cent), wood pulp and chips (0.05 per cent), and glass (0.10 per cent). The lowest export percentage is seen in products that have the potential to support circular economies, such as byproducts or crop residues.

In the case of ALDFG, most products made of natural materials are grouped with those of plastics or other materials. ALDFG's share of global exports is 0,02 per cent, of which fishing gear made with natural materials represents 0,003 per cent and other gear which, besides natural, also include plastic materials is 0,02 per cent. In the case of ropes and cords used for fishing activities, many of them can be made from natural biodegradable materials such as sisal and viscose. The data show that about 13 per cent of traded HS codes identified for fishing gear are made of natural materials, in the case of fishing lines.

With regards to fishing nets, substitute materials have little or no market presence, as most biodegradable or compostable fishing nets are still in research and development phases (See Box 5 on targeted initiatives and efforts to use plastic substitutes as well as plastic recycled materials for fishing gear).

Figure 6 below provides a further disaggregation of materials and products exported in three categories: raw material, intermediate/final products, and ALDFG; providing subcategories that differentiate products by their origin (mineral, trees and plants, crop residues, animal, byproducts, etc.) and within these subcategories a specific plastic substitute (e.g., for mineral-based, glass, aluminium and ceramics are illustrated according to their share of global exports).

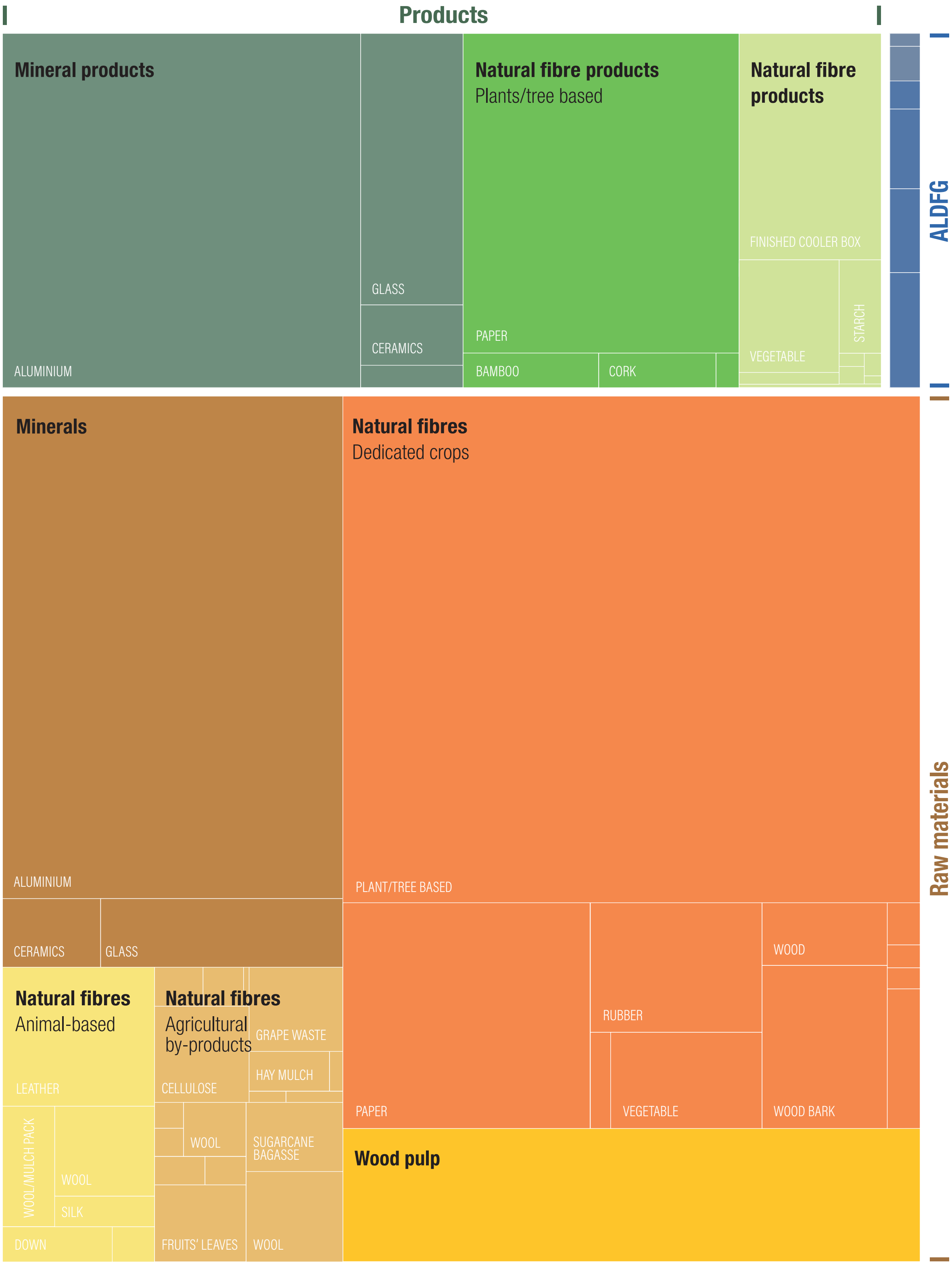
Figure 6. Share of global trade of plastic substitutes by type of source



Source: Compiled by authors, based on COMTRADE data 2020 and HS 2022 codes.

Note: Value of global exports indicated in billions of United States dollars and respective trade share.

Figure 6. (cont.) Share of global trade of plastic substitutes by type of source

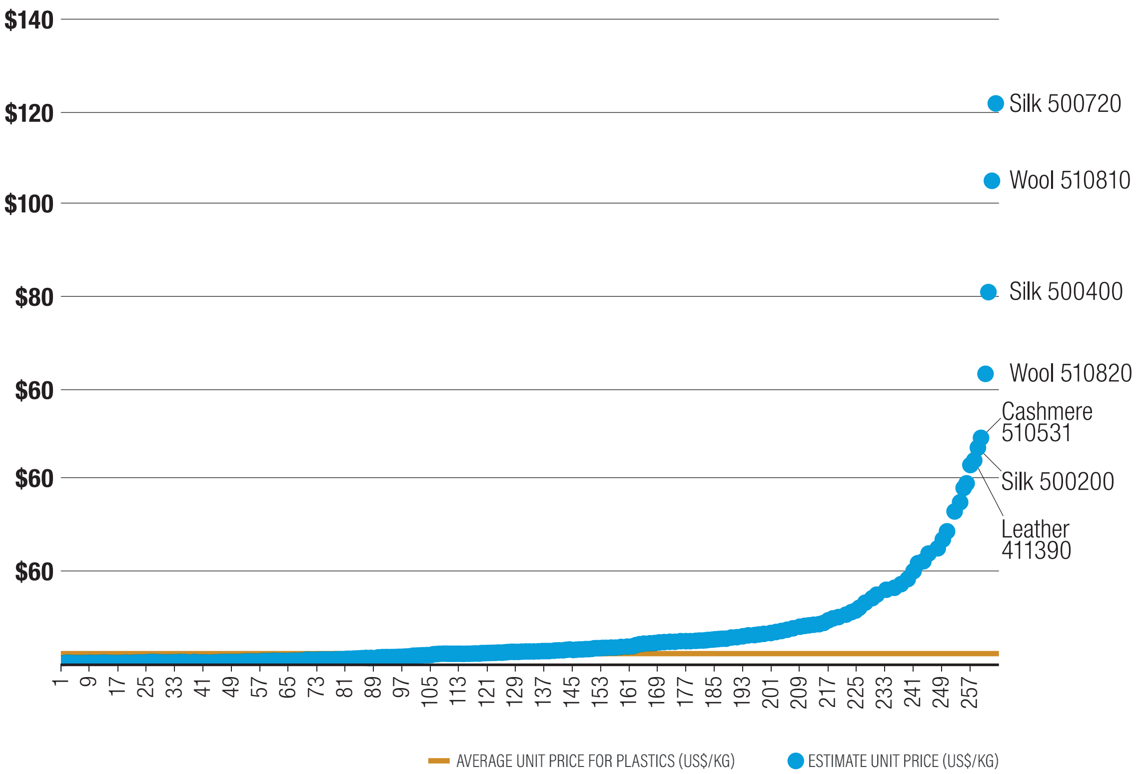


Source: Compiled by authors, based on COMTRADE data 2020 and HS 2022 codes.

Note: Value of global exports indicated in billions of United States dollars and respective trade share.

The export data also reveals that prices of plastics and their substitutes are substantially different. Using the same HS codes discussed previously, it is possible to assess unit prices based on trade value and quantum data available. Figure 7 below shows the unit price of substitute material or product and compares these prices with an average unit price in $ per kg for plastics. Plotting all substitute products identified, from lowest to highest unit price, comparing with a horizontal average line of unit price of plastics, it demonstrates that plastics are much cheaper than their substitutes. So, the price incentive is not to substitute them. The price differential can be attributed to various factors including lower production costs but also lower tariffs (as is shown below), and distortive subsidies to the polymers value chains. Given current conditions, market forces would themselves reproduce the unsustainable path of plastics use we currently experience.

Figure 7. Unit prices of plastic substitutes (material and products) in $ per kg



Source: Compiled by authors, based on COMTRADE data 2020 and HS 2022 codes.

3.3 Market access policies applied to plastics substitutes of the selected clusters

Trade policies applied by countries, especially those directly affecting access to markets, can have a significant impact on supply and demand of substitutes to plastics. These policies can affect the price, the product availability in markets, and could also contribute to ensuring products are safe for consumers. These policies can, however, go either way, facilitate or hinder purchases of materials and final products that can reduce plastic production and consumption, as products availability depend on many new frontiers of trade policy that include tariff and non-tariff measures (see Box 9).

Even though countries have reduced their most-favored nation (MFN) tariffs since the 2000's, and the preferential tariffs resulting from trade agreements, particularly in developed countries, the incidence and prevalence of non-tariff measures (NTMs) has risen. These policies can be highly effective in influencing sustainable outcomes if applied in a coordinated manner through multilateral, or regional negotiations.

Such policies, however, must strike a careful balance between environment, health, and social objectives on one hand, and economic growth on the other, as this is of paramount importance to the overall policy framework needed to support environmentally friendly substitutes to plastics.

Given the critical impact that such measures have on market access, the global and sectoral overview of plastics substitutes in this section delves into the tariff and non-tariff market access requirements that exporters must comply with to access international markets. It assesses what the measures are that are applied to the plastics substitutes identified, what policy space countries have for using these measures, and the potential effect these may have on prices.

Box 10. Defining tariffs and non-tariff measures

Tariffs are customs duties levied by governments on imported goods, which must be paid before entry into market. For example, these could be in terms of a percentage (such as a 7 per cent tariff on bagasse imports) or on a specific basis ($200 per ton), or both combined.

Non-tariff measures are policy measures – other than ordinary customs tariffs – that can potentially have an economic effect on international trade in goods, changing quantities traded, or prices, or both. These include:

- Technical measures, including SPS measures and TBT, which are product-specific requirements, mostly designed for public policy objectives to protect health, safety and the environment, such as packaging requirements, maximum residual limits of chemicals, and related inspections and certification; and
- Non-technical measures, a wide array of trade-related policies such as quotas, nonautomatic import licensing, rules of origin and price control measures.

While NTMs aim primarily to protect public health or the environment, they also affect trade through information, compliance, and procedural costs, and have been shown to be more restrictive than tariffs.

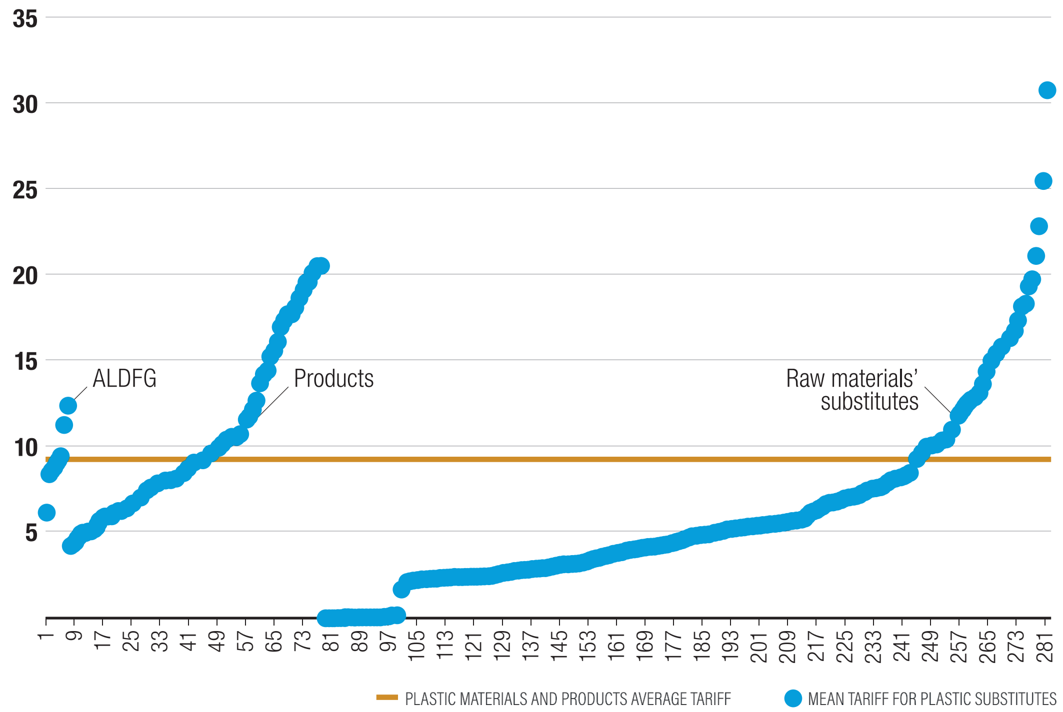
Source: UNCTAD (2019b)

3.3.1 Tariffs applied to substitutes to plastics

This section analyses import tariffs applied to raw materials and products' substitutes to plastics with an identified 6-digit HS code. Both materials and products are organized and provide an overview of import tariffs by subcategories as seen previously in this paper. A general overview of mean import tariffs applied to plastic substitutes is displayed in Figure 8 below, which shows that substitute products usually have higher import tariffs than plastics. Plastic raw materials and products generally enjoy low tariffs, concentrated below 10 per cent, while product substitutes range between around 5 per cent and 25 per cent - therefore many of them may face enhanced difficulties in becoming economically viable if needed to be imported. Raw materials substitutes are so diverse, and mostly of very low complexity in terms of productive capacities, that there is no clear pattern: most of them are below 10 per cent and results span from as low as 3 per cent to as high as 30 per cent.

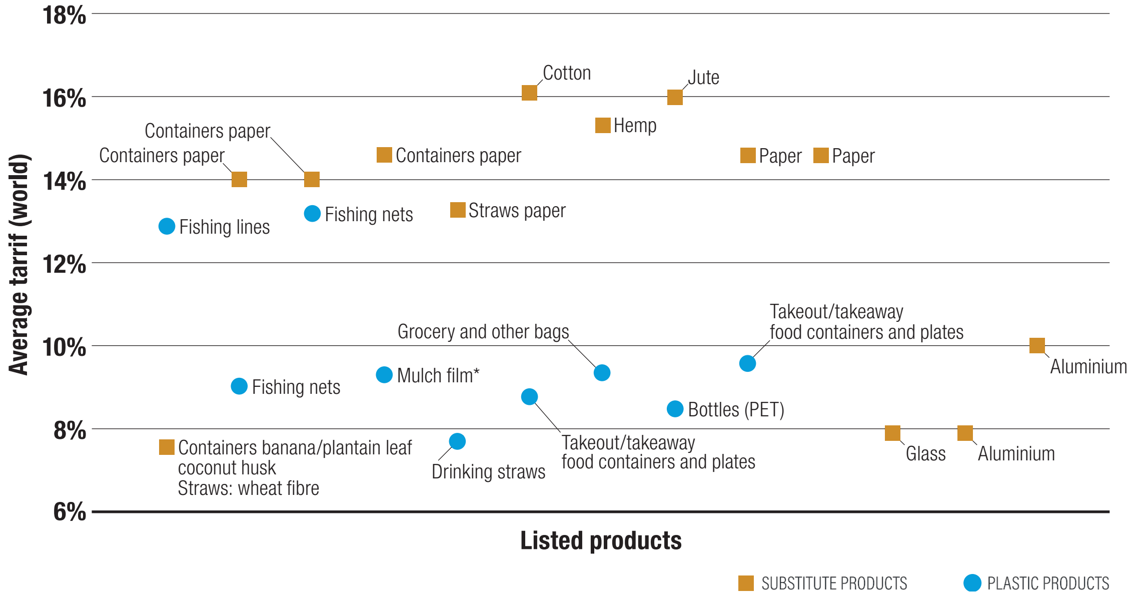
A more detailed comparison between some selected plastic products and their substitutes, Figure 9, reveals a clear difference between the two. For example, paper straws' global average tariff is 13.3 per cent, while plastic straws' global average tariff is 7.7 per cent. The same appears for paper container alternatives compared to plastic bags or bottles. Exceptions hold in the case of aluminum and glass, because of their widespread mass production globally, and for some very basic products, such as containers made of banana leaves or coconut husks.

Figure 8. Overview of average import tariffs for selected plastic and plastic substitutes materials and products



Source: Compiled by authors, based on COMTRADE / Observatory of Economic Complexity (OEC) data 2020 and HS 2022 codes.

Figure 9. Comparison of world average import tariffs applied to selected plastic products vs plastic substitutes

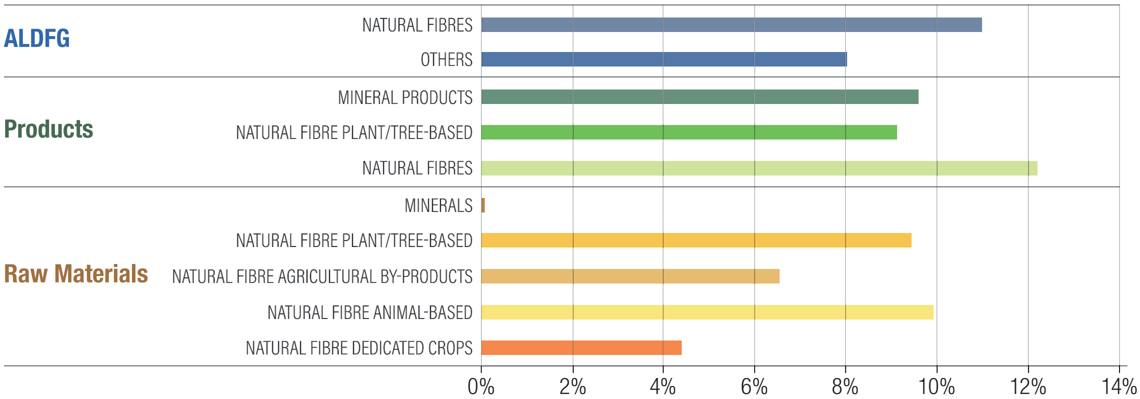


Source: Compiled by authors, based on OEC data 2020 and HS 2022 codes.

Note: Aluminium, paper, container paper and fishing nets are repeated in the graph because of different items represented in different HS codes. For example, Aluminium's are 761290, 761699 and 761510.

Similar results are obtained if HS codes are grouped by type of source and main subcategories (Figure 10 below).

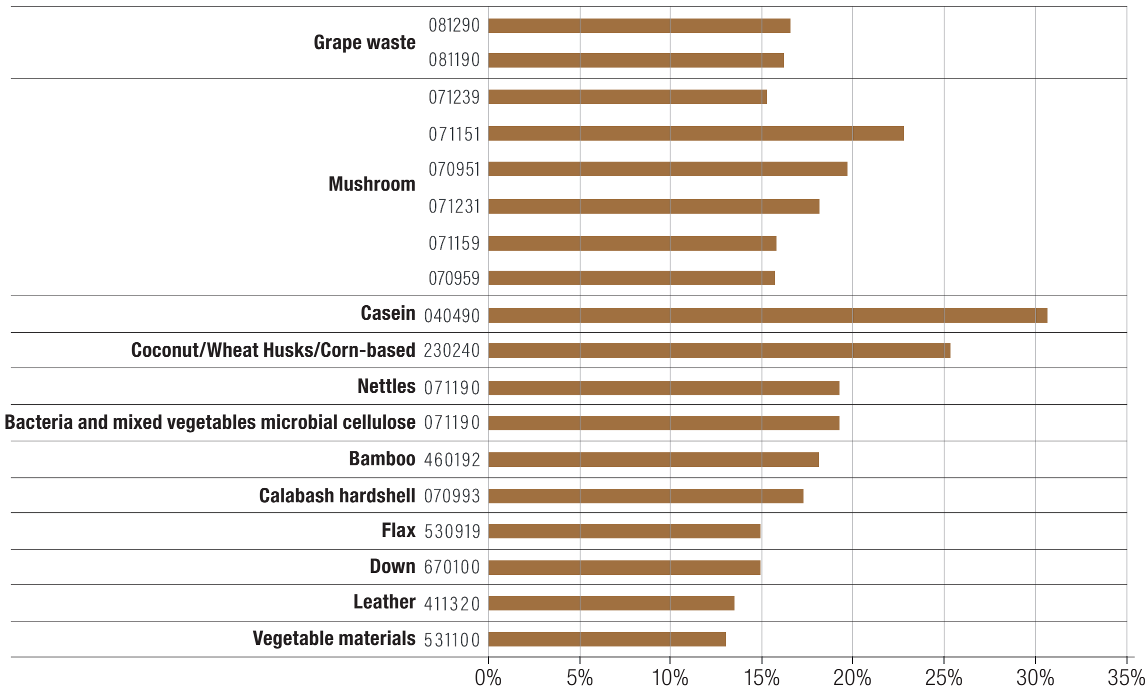
Figure 10. **Average import tariffs applied on substitutes to plastics by type of source**



Source: Compiled by authors, based on OEC trade data 2020 and HS codes revision 2022.

Figure 11 below shows that 18 HS codes, mostly new material substitutes as listed in Table 1, have applied tariffs above the highest tariffs applied to plastics raw materials (9.61 per cent), tariffs range between 13 and 30.70 per cent.

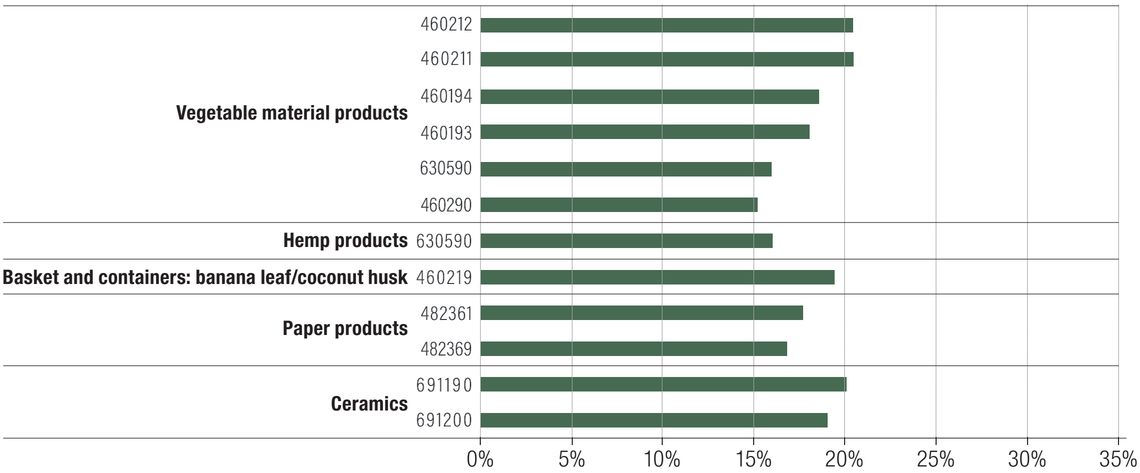
Figure 11. **Average import tariffs applied on selected plastic substitutes raw material**



Source: Compiled by authors, based on OEC data 2020 and HS 2022 codes.

Figure 12 on next page presents global average tariffs for substitute products made of vegetable materials, paper, ceramics and the results are between 15.20 and 20.50 per cent, while the highest tariff for plastics is around 13 per cent.

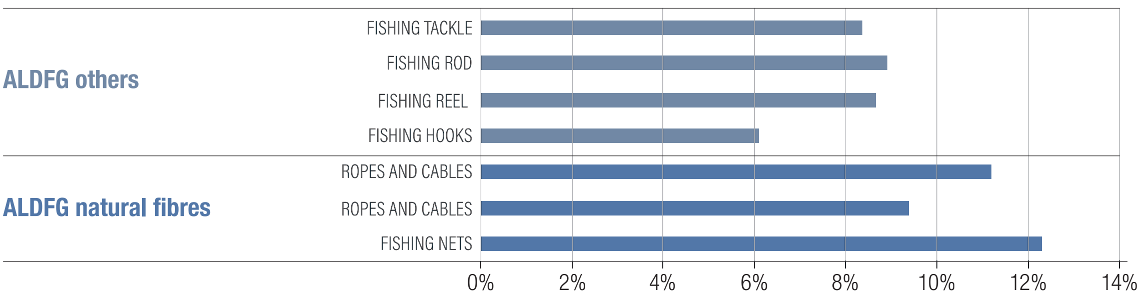
Figure 12. Average import tariffs applied on products made of plastic substitutes



Source: Compiled by authors, based on OEC data 2020 and HS 2022 codes.

Tariffs applied to fishing gear (Figure 13) increase prices by at least 8 per cent. This is important because any additional cost matters for small fisheries that require these inputs in large amounts, not only because of the end of life of the product but because these can be lost. Tariff data also reveals that HS codes for fishing gear made of natural fibres seem to have higher tariffs than those made completely of plastic materials.

Figure 13. Average import tariffs applied on ALDFG



Source: Compiled by authors, based on OEC data 2020 and HS 2022 codes.

In conclusion, the analysis found higher tariffs applied to a set of plastics substitutes, which suggests an important policy space to reduce tariffs so to create greater incentives to move towards plastics substitutes. This should be present both in multilateral trade agreements pursuing a more sustainable future, and bilateral agreements. Reducing costs for traders can trigger national and global supply and attract investment to the source country – in some cases investment could also be expected at other stages of the value chain in the source or partner country.

3.3.2 Non-tariff measures applied to plastic substitutes

Data on non-tariff measures (NTMs) are a vital complement to tariff data as NTMs may be more restrictive than tariffs. While non-tariff measures aim primarily to protect public health, product quality, or the environment, they also affect trade through information, compliance, and procedural costs (UNCTAD, 2019b). NTMs may decrease trade, e.g., when trade costs resulting from compliance with a regulation increase, or it may increase trade, e.g., when trust in foreign products increases. Understanding NTMs and enhancing their transparency can help traders identify the requirements they face, and can help policymakers, trade negotiators, and researchers to achieve the right balance between the reduction of trade costs and the preservation of public objectives (UNCTAD, 2022e).

NTMs comprise a wide area of policy measures – i.e., official legislation in force that applies to imports and to exports – that usually differs by country and product. To compare data on NTMs internationally is possible by using the NTMs classification, which includes over 400 codes that are grouped across 16 chapters. Databases such as UNCTAD's Trade Analysis Information System (TRAINS), which covers 100 economies, make NTM analysis possible as it allows for the identification of all regulations that traders of any product have to comply with in a certain market – i.e., regulations are coded by the NTM classification taxonomy and by product using the Harmonized System classification (HS).

Using the TRAINS database, three standard NTM indicators for plastics substitutes were calculated.[17] The indicators allow us to assess the use of NTMs, how often countries are applying NTMs, the most common types of NTM and the most regulated clusters of plastic substitutes. These indicators reveal the use of NTMs as policy instruments, but do not reveal how much NTMs would cost exporters and importers, nor if they are restricting or enhancing trade. The three indicators discussed in this section are:

- Frequency Index, which captures the per centage of products (at the 6-digit HS code) affected by one or more NTMs.
- Coverage ratio, which captures the share of trade subject to NTMs – unlike the frequency index, this uses trade values. It is weighted by import values rather than number of traded products.
- Prevalence score, which indicates the average number of distinct NTMs applied in a country to regulated products, thereby measuring the diversity and intensity of NTMs. (UNCTAD, 2019b).

A joint UNCTAD and World Bank publication (UNCTAD, 2018c) observed that developed countries tend to have deeper levels of regulation, covering more sectors and with a higher number of NTMs.

General results

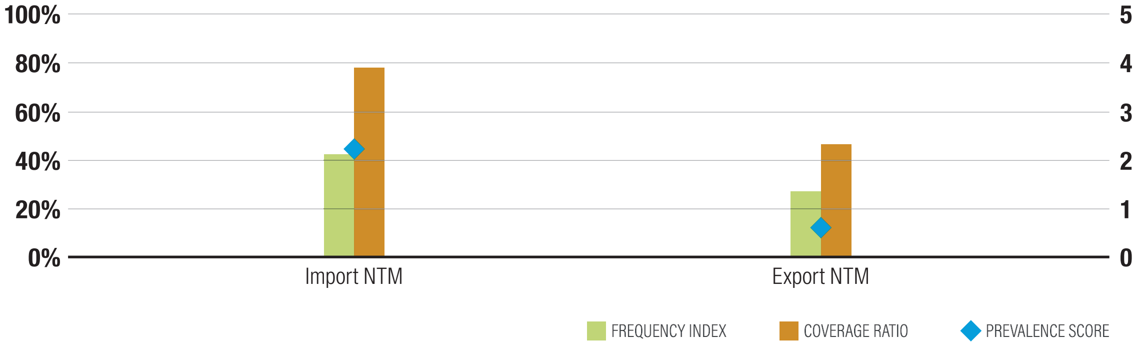
The results show that plastic substitutes for the selected clusters face a total of 150 different types of import measures and almost 30 different types of export measures. For imports, in all countries included, the indicators reveal that around 40 per cent of substitutes to plastics need to comply with at least one NTM (first green bar in Figure 14). In trade value this represents about 80 per cent of the import value of plastic substitutes (first yellow bar). Every imported product needs to comply with about two NTMs, on average (first blue diamond). As for exports, almost a third of exported substitutes to plastics need to comply with NTMs.

The NTM indicators also reveal significant differences between country groups (Figure 15). In the case of NTMs applied to imports, developed countries have on average three NTMs by traded product. This affects around 80 per cent of trade. Developing countries and least developed countries (LDCs) have between one and two NTMs. In contrast, NTMs that apply to exports are more prevalent in developing countries than in developed countries, both in terms of trade coverage and in the number of NTMs in place. Developed countries regulate more imports than exports of the studied plastic substitutes, while the opposite holds for LDCs which typically apply licenses and taxes for exporting – this policy may mirror countries concerns to ensure minimum quality to expand markets (increase importers' trust, compliance with partner country's regulations (e.g., pre-shipment), limit exports of certain products).

Annex 3 provides the NTM indicators by economy or territory.

17 NTMs calculations were based on an earlier subset of 265 HS codes of plastic substitutes, so the results should be interpreted as general trends and not exact figures.

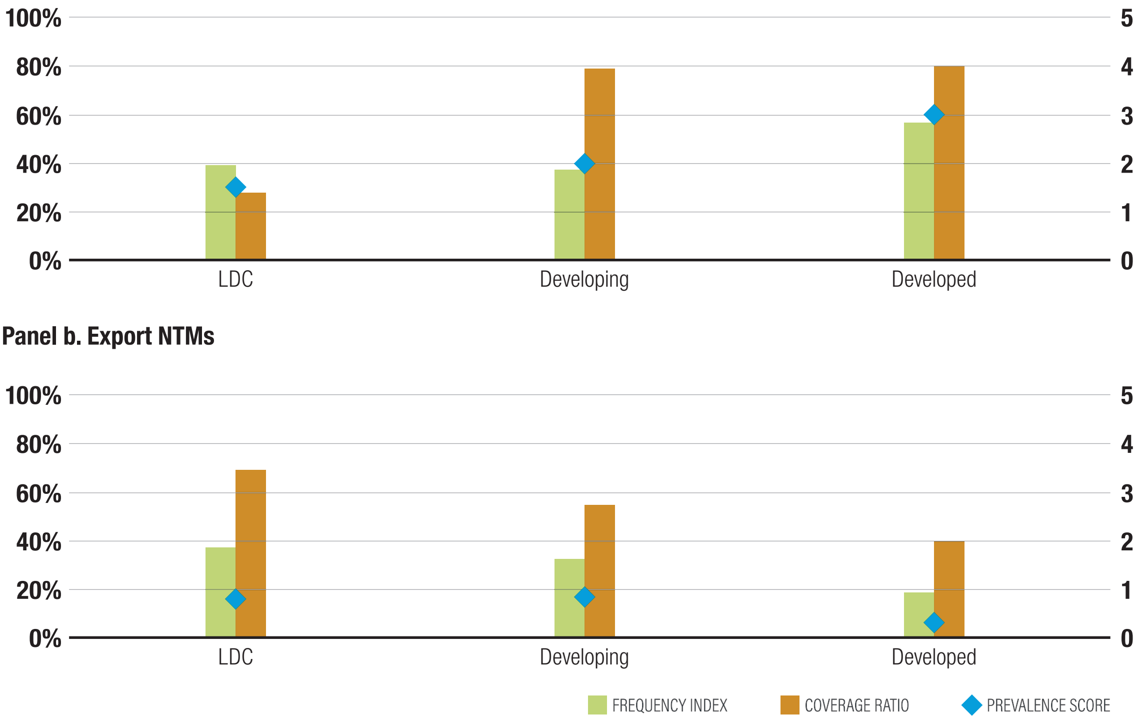
Figure 14. Global results



Source: Compiled by authors, based on TRAINS.

Figure 15. NTM indicators by development status

Panel a. import NTMs



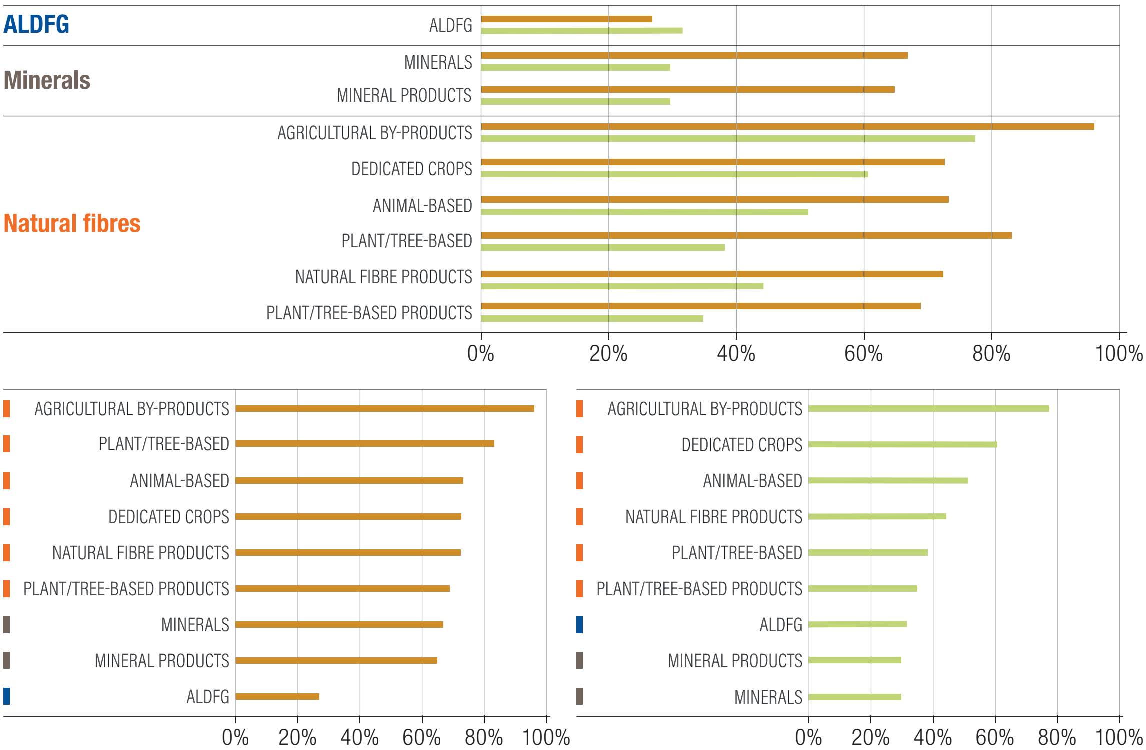
Source: Compiled by authors, based on TRAINS.

Results by cluster

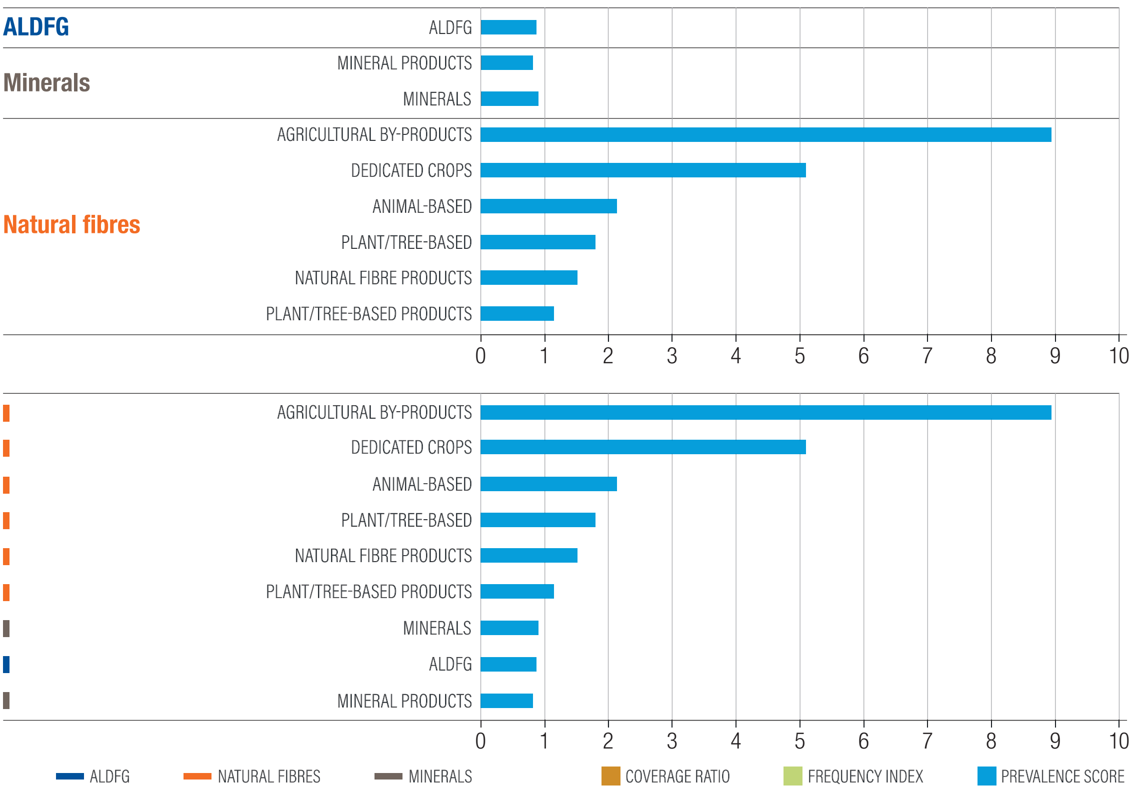
NTM data grouped by cluster of plastics substitutes discussed in Chapter 2 (Figure 16) shows that, in terms of NTMs applied to imports, the most regulated clusters are natural fibres from plant and tree-based products, dedicated crops, and agricultural by-products (left panel). Products of these clusters also face the highest number of NTMs. The indicators are lower for NTMs applied to exports (Figure 16 last two panels).

Figure 16. NTM indicators by sector

Panel a. Import NTMs: coverage and frequency



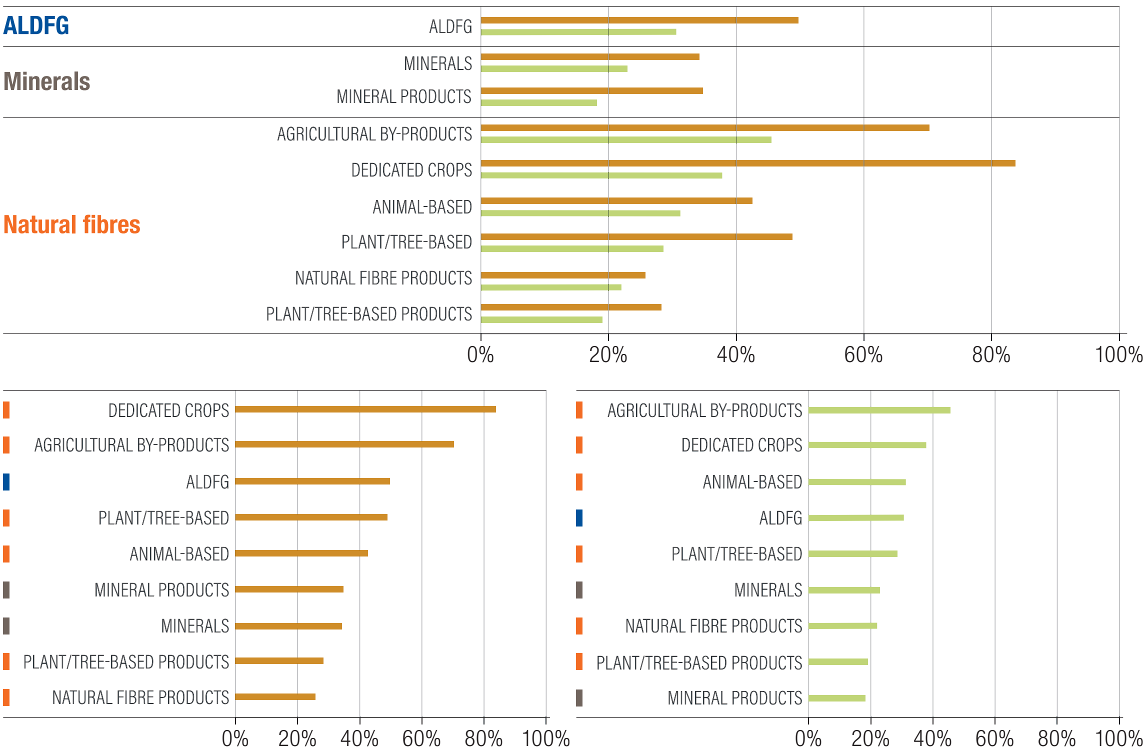
Panel b. Import NTMs: prevalence



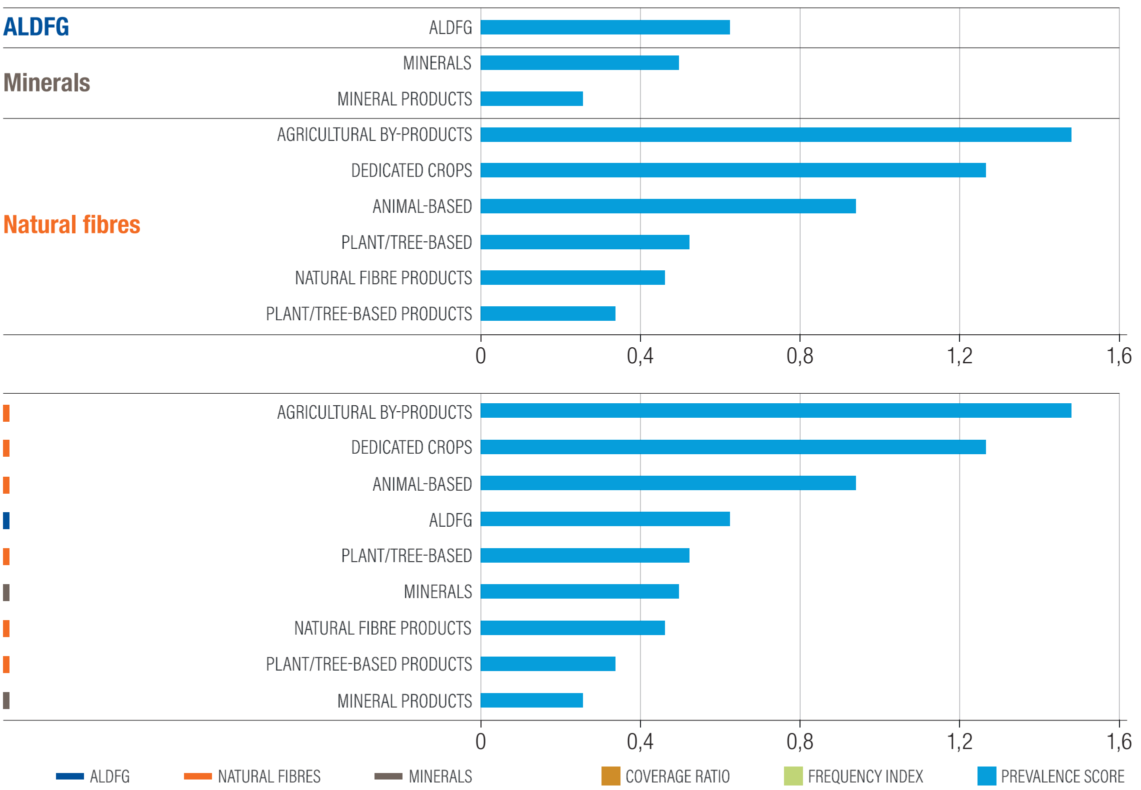
Source: Compiled by authors, based on TRAINS.

Figure 16. (cont.) NTM indicators by sector

Panel c. Export NTMs: coverage and frequency



Panel b. Export NTMs: prevalence



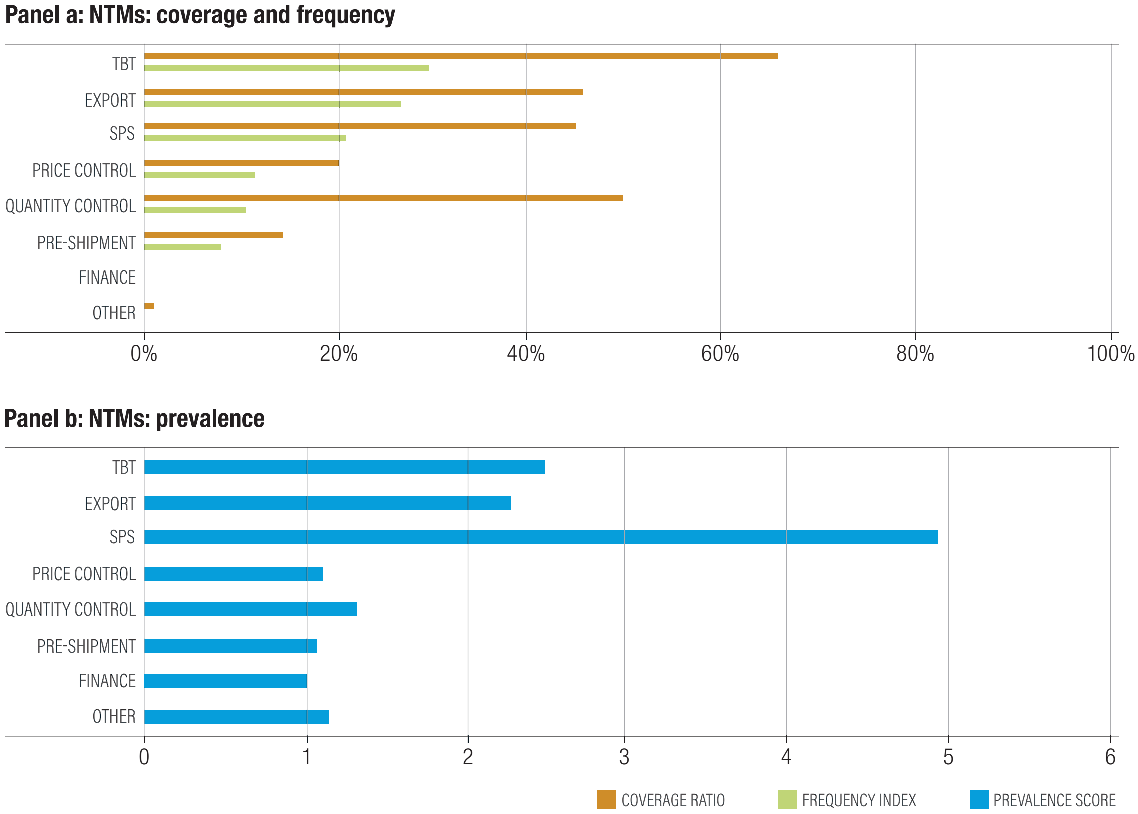
Source: Compiled by authors, based on TRAINS.

Results by type of non-tariff measure

About 30 per cent of the imported plastics substitutes studied must comply with at least one TBT measure, which represents more than 60 per cent of world imports. The next most common import measure used concerns requirements for licences, quotas, or other quantity control measures – representing 40 per cent of world imports. In the case of NTMs applied to exports, more than 20 per cent of plastic substitutes face at least one NTM, representing around 40 per cent of world exports.

The share of SPS measures, which mostly concern food and agriculture products, is lower, at 21 per cent of the global value of imports of substitutes to plastics. However, SPS has the highest value in terms of the prevalence score as each imported product needs to comply with an average of six SPS measures, as opposed to three TBT measures.

Figure 17. NTM indicators by type of measure



Source: Compiled by authors, based on TRAINS.

4

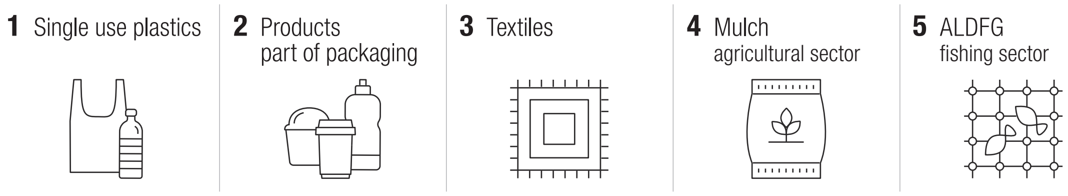
FINDINGS

4. Findings

As the world looks for solutions to address climate change amid growing concerns regarding negative environmental impacts caused by human habits, the problem of plastics is gaining momentum. There is a sober awareness that pollution caused by plastics needs a more aggressive approach while designing policies to prevent future plastic dependency and mismanagement. Nevertheless, plastics are here to stay as they provide some important functions for today's societal needs. Therefore, plastic substitutes are not a solution to be implemented overnight without a carefully designed and informed set of policies, as well as a system that would incentivize such substitution and prevent any further potential harm to the environment and human health. For plastic substitutes to become a viable solution in the mid and long-term, decisive global action is needed today. Moving away from silo policies and towards coherence and coordination between measures to address plastic pollution across the plastic life cycle and in favor of circular economies is an important initial step.

4.1 Key findings

This paper provides a distinction between plastic substitutes and plastic alternatives and provides a clear definition for both: plastic alternatives can thus include bioplastics or biodegradable plastics, while the substitutes are natural materials from mineral, marine, plant, or animal origin, that have similar physical properties to fossil fuel-based plastics. Based on this, clusters that contribute the most to plastic waste and put a significant pressure on countries' waste management system capacities, and the oceans were identified:



Currently, a list of all plastic substitutes in existence or that are being developed does not exist. Therefore, an **extended illustrative list of materials and product substitutes** for plastics was created. The 282 HS codes representing potential substitutes for plastics constitute an initial basis for analysis and policy action on various materials and products which can help steer society away from plastics. Their **total global exports in 2020 was $388 billion of which approximately two thirds are raw materials ($258 billion), $125 billion were products, and $4 billion was ALDFG**. This is a significant number, which can be upscaled with the right set of policy support and incentives.

Looking into these five clusters a few **innovative and scalable examples of plastic substitutes were identified and showcased** in more detail. This is, however, an ongoing process and can only be approached by continuously identifying substitutes that can perform similar functions to plastics on a case-by-case basis, and as we see more innovations in this area, new substitutes could materialize in the future. Similarly, information on each product cluster is scattered across different sources.

The paper recognizes that the discussion on **phasing out plastics requires a detailed assessment** about the type of substitutes, their availability, and limitations. The data support the claims that the most suitable substitute to plastic may not be equally applied to all fossil fuel-based plastics with similar properties, or across countries, and not even within sectors but it depends on a local context in terms of availability of materials, consumers' behavior, country's capacity to process waste, and substitute's reusability. This is reinforced by various **life cycle analyses of plastic substitutes** published recently (e.g., UNCTAD, UNEP, and WB) and illustrated in the report with an example of jute bags from the SMEP programme. Hence, a broader set of impacts considered by the LCA is important, such as assessment of litter, health, long-term impacts on ecosystems, and social and gender impacts.

Two indicators were used to determine the **economic viability of material substitutes** - Revealed Comparative Advantage and Recovery/recycling rate. Findings identified ideal substitutes which are located around RCA above 1 (thus the country already has a revealed comparative advantage, or competitive productive capacities) and with a recycling rate above 60 per cent. Furthermore, there are countries identified that have the capacity (RCA above 1) and could easily move to the preferred area but need to invest in a waste management system that would increase their recovery/recycling rates. Policies to improve the RCA while improving the recovery/recycling rate could also be suggested, but results would require longer term and more substantive policies to combine better recycling rates and more complex productive capacities.

Despite the above identified limitations on the usage of certain HS codes, a **total of 282 6-digit HS codes for plastic substitutes were identified** including with their corresponding HS chapters. A broad array of substitutes to plastics are covered under the HS Chapter 44 (Wood and articles of wood), 47 (Pulp of wood or other fibrous cellulosic material), 48 (Paper and paperboard), 51 (Wool, fine or coarse animal hair, yarn and woven fabric), 53 (Vegetable textile fibres; paper yarn and woven fabrics of paper yarn), and 76 (aluminium and articles thereof). Furthermore, the paper intentionally gives examples of some highly innovative plastic substitutes, new materials that could replace or even improve functionality of plastic or usage of plastic materials during product production, but for which an applicable HS code doesn't exist yet and are thus presented as an example of the HS codes' limitations this paper encountered.

Even though in terms of total global exports, the share of plastic substitutes (2 per cent share) is less than that of plastics (5 per cent share of global exports) these are nevertheless significant numbers that can be scaled with adequate policy support and incentives. Trade data also reveal that raw materials are the most traded in respect to final product, which **suggests that the development of substitutes to plastics is taking place outside the source countries**. A fact that is indeed a missed opportunity (or an opportunity to grasp) for raw material exporting countries, but also for partnerships between countries – regionally and internationally.

Using the list of identified plastic substitutes with 6-digit HS codes, the data for unit price of these substitute materials or products compared with **an average unit price for plastics demonstrates that plastics are usually much cheaper than their substitutes**. Thus, the price incentive is not to substitute plastic.

A general overview of **mean import tariffs applied to plastic substitutes indicates that substitute products usually face higher import tariffs than plastics**. Plastic materials and products generally enjoy low tariffs and are concentrated below 10 per cent, while product substitutes range between 5 per cent and 25 per cent - therefore many of them will face enhanced difficulties in becoming economically viable if needed to be imported. So, in addition to having a lower price, a market incentive not to substitute, plastics also enjoy lower tariffs.

Therefore, higher tariffs applied to a set of products and raw material plastics substitutes **suggest an important policy space to reduce tariffs so to create greater incentives to move towards plastics substitutes**. That should be present both in multilateral trade agreements pursuing a more sustainable future, and bilateral agreements. Reducing costs for traders can trigger national and global supply, and attract investment to the source country – in some cases investment could also be expected at other stages of the value chain in the source or partner country.

Apart from tariffs that potentially place plastic substitutes at a disadvantage, non-tariff measures can equally, if not even more, harm trade flows and thus the mainstreaming of plastic substitutes. Analysis in this paper shows that around 40 per cent of the imported substitutes to plastics in the world need to comply with at least one NTM, which represents about 80 per cent of the value of these imported goods. Almost a third of exported substitutes to plastics need to comply with NTMs. **Products which are most regulated are natural fibres from plant and tree-based products, dedicated crops, and agricultural by-products and these also happen to be the products with higher numbers of NTMs**. This is due to the high number of regulations for these products.

In addition to the hurdle NTMs themselves impose on developing countries and sectors related to plastic substitutes such as agriculture, another important element that hinders international trade, in particular exports from developing countries burdened by NTMs, are their business enabling environments (BEE). Requiring a **developing country to comply with regulations and processes that are often time consuming and costly prevents many, especially small and mid-sized companies, from engaging in global trade**. Information about requirements, for example on SPS and TBT, is often limited and administrative processes untransparent and costly. With post-COVID-19 accelerated digitization of trade-related administrative procedures in developing economies some of the burden might be alleviated, however, opportunities that comparable companies in developed economies, with well-functioning and supporting enabling environments have, still put others at a disadvantage.

4.2 The way forward

This paper outlined some of the crucial challenges policy makers will need to address in order to tackle plastic pollution and create incentives for plastic substitutes. From identifying some potential plastic substitutes that could become more prominent as they develop productive capacities, but bearing in mind their potential environmental impact, to changes needed in today's trading system that would incentivize this transition, including trade incentives. Thus, this paper i) **provides clusters which can be a basis for countries to work on**, and ii) provides **corresponding identified HS codes for plastic substitutes that should be considered as an evolving list**.

When discussing enabling conditions for plastic substitutes, findings iii) on **currently applied tariffs show that there is not a level playing field for plastic substitutes versus plastics**, and iv) **due to currently low prices of plastics, countries could explore adjusting tariffs applied to plastics or phasing out fossil fuel subsidies**. Furthermore, v) **countries can explore policy options to enable sunrise industries around plastic substitutes, where they have comparative advantages, capacities for recovery, recycling, and potential for job creation**.

Environmental impact being of utmost importance for a substitute to plastic to be considered it needs to be emphasized that vi) **additional exploratory work needs to be done to identify existing innovative products which could perform the role of plastic substitutes**, and that vii) **plastic substitutes are only one instrument in the policy-making toolbox for countries to address plastic pollution**. Based on viii) LCA considerations, which point to potential problematic aspects of some substitutes, **countries need to come up with a minimum set of LCA indicators on which actionable policy can be based, in order to define substitutes which should be produced**.

Assisting developing countries is crucial as ix) **material substitution may provide an opportunity for productive capacities development which generate jobs locally**. For this shift to be inclusive and economically sustainable a x) **further research on gender aspects of transitioning to plastic substitutes is needed, due to potential changes in labor structures that would disproportionally affect women**, along with xi) **mapping of existing and developing new, tailored, financial instruments, to help scale promising substitute solutions for broader market rollout**. The latter could be supported by multilateral development banks across regions leveraging their environmental efforts, knowledge, and dedicated funds.

REFERENCES

Akenji, L., Bengtsson, M., Kato, M., Hengesbaugh, M., Hotta, Y., Aoki-Suzuki, C., Gamaralalage, P. J. D., & Liu, C. (2019). Circular economy and plastics: A gap-analysis in ASEAN member states. European Commission Directorate General for Environment and Directorate General for International Cooperation and Development. Association of Southeast Asian Nations (ASEAN). Available at: https://asean.org/book/circular-economy-and-plastics-a-gap-analysis-in-asean-member-states/

Barrowclough, Deere Birkbeck and Christen (2020). Global trade in plastics: insights from the first life-cycle trade database. UNCTAD Research Paper No. 53 UNCTAD/SER.RP/2020/12. Available at: https://unctad.org/system/files/official-document/ser-rp-2020d12_en.pdf/

Chamas et al (2020). Degradation Rates of Plastics in the Environment. ACS Sustainable Chemistry & Engineering, Vol. 8/9, pp. 3494-3511. Available at: http://dx.doi.org/10.1021/acssuschemeng.9b06635

CIEL (2019). Plastic & Climate: The Hidden Costs of a Plastic Planet. Available at: https://www.ciel.org/project-update/plastic-climate-the-hidden-costs-of-a-plastic-planet/

EIP-AGRI (2020). Biodegradable mulch films to reduce plastic footprint in agriculture. Press Article online. Available at: https://ec.europa.eu/eip/agriculture/en/news-events/press-media/press-release/biodegradable-mulch-films-reduce-plastic-footprint/ (Accessed on: 1 October, 2022)

Espiner, T. (2022) Notpla: UK plastic-alternative developer among £1m Earthshot Prize winners. *BBC News, 2* December. Available at: https://www.bbc.com/news/business-63841761/ (Accessed on: 11 January, 2023).

Euractive (2022). Sustainable products initiative. Special Report. https://en.euractiv.eu/wp-content/uploads/sites/2/special-report/Sustainable-products-initiative-Special-Report.pdf/ (Accessed on: 10 November, 2022).

FAO (2016). *Abandoned, lost and discarded gillnets and trammel nets. Methods to estimate ghost fishing mortality, and the status of regional monitoring and management.* FAO Fisheries and Aquaculture Technical Paper No. 600. Rome. Italy. Available at: https://www.fao.org/3/i5051e/i5051e.pdf/

FAO (2021). Assessment of agricultural plastics and their sustainability. A call for action. Rome. Available at: https://doi.org/10.4060/cb7856en/

Feber, (2022). Creating good packaging for packaged goods. McKinsey Podcast. Available at: https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/creating-good-packaging-for-packaged-goods/

Fortuna Cools (2022). Workshop on sustainable and effective substitutes and alternatives for plastics: WTO and UNCTAD. 6 December 2022. Available at: https://unctad.org/system/files/non-official-document/ditc-ted-06122022-plasticsWTO-FortunaCools-Q2.pdf/

Geyer, R., Jambeck, J.R. and Law, K.L. (2017). Production, use, and fate of all plastics ever made. Science advances, 3(7), p.e1700782.

Global Ghost Gear Initiative (2022). https://www.ghostgear.org/ (Accessed on: 1 October 2022).

Hausmann, R., Hidalgo, C.A., Bustos, S., Coscia, M. and Simoes, A., (2013a). *The atlas of economic complexity: Mapping paths to prosperity*. Mit Press.

Hausmann, R., Hidalgo, C., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simoes, A., Yildirim, M. (2013b). The Atlas of Economic Complexity. Available at: https://atlas.cid.harvard.edu/ (Accessed on 20 October 2022)

Hamwey, R., Pacini, H. and Assunção, L.. (2013). *Mapping green product spaces of nations.* The Journal of Environment & Development, 22(2), pp.155-168.

Hira, A., Pacini, H., Attafuah-Wadee, K., Vivas-Eugui, D., Saltzberg, M. and Yeoh, T.N., (2022). *Plastic Waste Mitigation Strategies: A Review of Lessons from Developing Countries*. Journal of Developing Societies, 38(3), pp.336-359. https://journals.sagepub.com/doi/epub/10.1177/0169796X221104855

Hira, A., Pacini, H., Attafuah-Wadee, K. and Hassall, J., 2022. *Sustainable Manufacturing and Environmental Pollution Programme (SMEP): A Circular Economy Experiment in the Global South*. Journal of Developing Societies, 38(3), pp.287-309. Available at: https://journals.sagepub.com/doi/epub/10.1177/0169796X221106013

IAEA (2021). NUTEC Plastics: A nuclear solution to plastic pollution. Roundtable for Asia and the Pacific region. Available at: https://sdgs.un.org/sites/default/files/2021-09/nutec_rt_asiapacific.pdf/

Link, J., Segal, B. and Casarini, L.M., 2019. A*bandoned, lost or otherwise discarded fishing gear in Brazil: A review*. Perspectives in Ecology and Conservation, 17(1), pp.1-8.

Lomartire, S., Marques, J.C. and Gonçalves, A.M., 2022. *An Overview of the Alternative Use of Seaweeds to Produce Safe and Sustainable Bio-Packaging*. Applied Sciences, 12(6), p.3123. Available at: https://mdpi-res.com/d_attachment/applsci/applsci-12-03123/article_deploy/applsci-12-03123-v2.pdf?version=1647679466/

McKinsey Company (2022). *Climate impact of plastics*. Chicago, USA. Available at: https://www.mckinsey.com/industries/chemicals/our-insights/climate-impact-of-plastics/

Morgan, A.C. 2011. Fish Aggregating Devices and Tuna: Impacts and Management Options. Ocean Science Division, Pew Environment Group, Washington, DC. Available at: https://www.pewtrusts.org/~/media/legacy/uploadedfiles/peg/publications/report/pegosdfadsenglishfinalpdf.pdf/

OECD, 2022a. Global Plastics Outlook: Policy scenarios to 2060. Available at: https://www.oecd-ilibrary.org/sites/aa1edf33-en/index.html?itemId=/content/publication/aa1edf33-en/

OECD, 2022b. Plastic pollution is growing relentlessly as waste management and recycling fall short. Available at: https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm/

Pew Charitable Trust and Systemiq, 2020. Available at: https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf/

Portsmouth University(2023) Global Plastic Policy Reviews, Downstream Initiatives. Available at: https://plasticspolicy.port.ac.uk/plastic_cycle/downstream/?_plastic_cycle=downstream/

ReportLinker, 2022. Textile Global Market Report 2022. Available at: https://www.globenewswire.com/news-release/2022/04/06/2417253/0/en/Textile-Global-Market-Report-2022.html/

Richardson, Hardesty, and Wilcox (2022). Science advances. Vol 8, Issue 41, 12 Oct 2022. Available at: Global estimates of fishing gear lost to the ocean each year | Science Advances

Royer, S.J., Ferrón, S., Wilson, S.T. and Karl, D.M., 2018. Production of methane and ethylene from plastic in the environment. PloS one, 13(8), p.e0200574.

SAPEA2019. A Scientific Perspective on Micro-Plastics in Nature and Society, Science Advice for Policy by European Academics. Available at: http://dx.doi.org/10.26356/microplastics/

Schröder, P. and Barrie P. (2022). *Global roadmap for an inclusive circular economy for Stockholm+50*. The Chatham House. London, United Kingdom. Available at: https://static.resourcetrade.earth/2022-05-23-stockholm50-circular-economy-roadmap-FINAL.pdf/

Simoes, A., Hidalgo, C. (2011). The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development. Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence.

SMEP, Instituto17 and UNCTAD, SMEP Trade and Pollution Dashboard. Available at: shorturl.at/DMW24 (Accessed on 20 October 2022).

SMEP (2022). The SMEP plastics intervention. Available at: https://smepprogramme.org/procurement/plastics-intervention/. (Accessed on 18 January, 2023).

SMEP (2022a) Plastic Waste Mitigation Strategies: A Review of Lessons from Developing Countries. In: Journal of Developing Societies, Volume 38, Issue 3. Available at: https://journals.sagepub.com/doi/full/10.1177/0169796X221104855#bibr17-0169796X221104855.

UNCTAD (2016). Guidelines to Collect Data on Official Non-Tariff Measures, January 2016 version. UNCTAD/DITC/TAB/2014/4. New York and Geneva.

UNCTAD (2018a). Global trade in plastics: insights from the first life-cycle trade database. Available at https://unctad.org/webflyer/global-trade-plastics-insights-first-life-cycle-trade-database/.

UNCTAD (2018b). 'Seaweed' pencil shows untapped economic potential of marine resources. Available at: https://unctad.org/news/seaweed-pencil-shows-untapped-economic-potential-marine-resources_/ (Accessed: 15 November 2022).

UNCTAD and World Bank (2018c). The Unseen Impact of Non-Tariff Measures. Insights from a New Database. United Nations and the World Bank. UNCTAD/DITC/TAB/2018/2

UNCTAD (2019a). Advancing Sustainable Development Goal 14: Sustainable fish, seafood value chains, trade and climate. Available at: https://unctad.org/system/files/official-document/ditcted2019d3_en.pdf/

UNCTAD (2019b). International Classification of Non-tariff Measures. United Nations publication. Sales No. E.19. II. D.14. New York and Geneva.

UNCTAD (2019c). Material substitutes to address marine plastic pollution and support a circular economy. Available at: https://unctad.org/webflyer/material-substitutes-address-marine-plastic-pollution-and-support-circular-economy/

UNCTAD (2021a). How to build concerted multilateral action on plastic pollution_ Available at: https://unctad.org/news/how-build-concerted-multilateral-action-plastic-pollution/

UNCTAD (2021b). Enabling concerted multilateral action on plastic pollution and plastics substitutes. Available at: https://unctad.org/webflyer/enabling-concerted-multilateral-action-plastic-pollution-and-plastics-substitutes/

UNCTAD (2021c). Manufacturing Pollution in Sub–Saharan Africa and South Asia. Available at: https://unctad.org/system/files/official-document/ditctedinf2021d6_en.pdf

UNCTAD (2021d). The Bridgetown Covenant: From inequality and vulnerability to prosperity for all. TD/541/Add.2 - 10 Nov 2021. Available at: https://unctad.org/system/files/official-document/td541add2_en.pdf

UNCTAD (2021e). Jamaican start-up shows potential of plastics substitutes. Press release. Available at: https://unctad.org/news/jamaican-start-shows-potential-plastics-substitutes/. (Accessed on November 13, 2022).

UNCTAD (2022a). Chair's Summary, 4th Oceans Forum: A shift to a sustainable ocean economy: Facilitating post-COVID-19 recovery and resilience. Available at: https://unctad.org/system/files/information-document/4th-Oceans-Forum-ChairsSummary-v7.pdf

UNCTAD (2022b). Substitutes for single-use plastics in sub-Saharan Africa and south Asia. Available at https://unctad.org/system/files/official-document/tcsditcinf2022d3_en.pdf

UNCTAD (2022c). UNCTAD Plastic Trade database. Available at: https://unctadstat.unctad.org/wds/

ReportFolders/reportFolders.aspx

UNCTAD (2022d). Global plastics trade hits record $1.2 trillion. Available at: https://unctad.org/data-visualization/global-plastics-trade-reached-nearly-1.2-trillion-2021 (Accessed: 15 November 2022).

UNCTAD (2022e). Non-tariff measures from A to Z. Available at: https://unctad.org/system/files/official-document/ditctab2021d3_en.pdf/

UNEA (2022). Report from the resumed Fifth Session of the United Nations Environment, 28 February - 2 March 2022. Resolutions on Enhancing Circular Economy as a contribution to achieving sustainable consumption and production; Resolution to end plastic pollution: towards an international legally binding instrument; and the Resolution on sound management of Chemicals and Waste. Available at: https://www.unep.org/news-and-stories/press-release/un-environment-assembly-concludes-14-resolutions-curb-pollution/

UNEP (2016). Marine Plastic Debris and Microplastics: Global Lessons and Research to Inspire Action and Guide Policy Change. Available at: https://wedocs.unep.org/20.500.11822/7720/ (Accessed: 15 November 2022)

UNEP (2021). Addressing Single-use Plastic Products Pollution Using a Life Cycle Approach. Available at: https://www.lifecycleinitiative.org/wp-content/uploads/2021/02/Addressing-SUP-Products-using-LCA_UNEP-2021_FINAL-Report-sml.pdf/

UNEP (2022). Our planet is choking on plastic. Available at: https://www.unep.org/interactives/beat-plastic-pollution/ (Accessed: October 10, 2022).

UNGA (2017). Our ocean, our future: Call for action. Resolution 71/312 adopted on the 6th of July 2017. Available at https://digitallibrary.un.org/record/1291421?ln=en.

Vaca Eyzaguirre and Deere Birkbeck (2021). Plastic Pollution and Trade Across the Life Cycle of Plastics: Options for Amending the Harmonized System to Improve Transparency. TESS. Available at: https://www.ciel.org/project-update/plastic-climate-the-hidden-costs-of-a-plastic-planet/

Velandia, M., DeLong, K.L., Wszelaki, A., Schexnayder, S., Clark, C. and Jensen, K., 2020. *Use of polyethylene and plastic biodegradable mulches among Tennessee fruit and vegetable growers*. HortTechnology, 30(2), pp.212-218.

Vivas and Barraclough (2021). Plastic Production and Trade in Small States and SIDS: The Shift Towards a Circular Economy. Commonwealth Secretariat. Available at https://production-new-commonwealth-files.s3.eu-west-2.amazonaws.com/migrated/inline/ITWP%202021_01_0.pdf/.

WEF, Ellen Macarthur Foundation, McKinsey & Co, 2016. A New Plastics Economy – Rethinking the Future of Plastics. Available at: https://ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics/.

World Economic Forum (2022). We know plastic pollution is bad – but how exactly is it linked to climate change?. Available at: https://www.weforum.org/agenda/2022/01/plastic-pollution-climate-change-solution/ (Accessed on October 10, 2022).

World Economic Forum (2022b). Top 25 recycling facts and statistics for 2022. Available at: https://www.weforum.org/agenda/2022/06/recycling-global-statistics-facts-plastic-paper/ (Accessed on October 10, 2022).

World Bank (2022). Where Is the Value in the Chain? : Pathways out of Plastic Pollution. Washington, DC. Available at:. https://openknowledge.worldbank.org/handle/10986/37285/.

ANNEX 1

Chair's Summary, 4th UN Oceans Forum: A shift to a sustainable ocean economy: Facilitating post-COVID-19 recovery and resilience (as related to plastic litter and other ocean waste challenges) (2022).

Addressing trade-related aspects of marine litter and plastic pollution

1. The recent United Nations Environment Assembly resolution on plastics pollution (UNEA 5.2) adopted in March 2022 has galvanized the commitment of the international community to tackle this issue at a global scale. As a result of this resolution, countries committed to develop by 2024, a treaty with binding elements designed to bring an end to plastic pollution. The resolution is considered one of the most important global achievements on pollution governance since the Paris Agreement on Climate Change in 2015. The 4th Oceans Forum is one of the first opportunities to reflect on the resolution and provide clear recommendations on how to pave the way for ensuring that work towards a United Nations treaty addresses the full lifecycle of plastics, including production, design and disposal while providing the most robust protections for health, climate, biodiversity, and human rights.

2. Together with complementary efforts at the multilateral trading system, such as the continuous work of the Informal Dialogue on Plastics at the WTO, the Basel Convention Plastic Waste Amendment, and improvements of the Harmonized System by the World Customs Organization, the UNEA process has launched an important road towards a United Nations Treaty, which if adopted, can contribute to a policy harmonization at the national level.

3. The panelists and participants made the following recommendations based on discussions:

> **d.** Addressing global challenges requires global responses - the problem of plastic pollution requires a collective and coordinated response which has been acknowledged by countries' commitments at the UNEA 5.2, the Commonwealth Blue Charter, and by the ministerial statement of the Informal dialogue on Plastics at WTO; by recognizing that this problem affects us all, all nations and stakeholders must be encouraged to take meaningful action
>
> **e.** Intensify multilateral cooperation to accelerate the adoption of a United Nations treaty on ending plastic pollution, backed by recommendations from the science-policy panel established at UNEA 5.2 by 2024
>
> **f.** At the national level, promote a more aggressive usage of economic instruments to support government's ambitions on plastic waste management and the transition to the circular economy, including by promoting material substitutes to plastics via differentiated tax strategies, regulations, industrial policy, and green public procurement.
>
> **g.** At the multilateral level, promote the further development of the Harmonized System by the inclusion of special classifications relevant to material substitutes and alternatives to facilitate the adjustment of tariff schedules that will promote material substitutes and alternatives to plastics, and disincentivize trade in highly polluting, single-use plastics and hazardous plastic materials, control plastic waste trade, facilitate trade of services necessary for waste avoidance, management, and recycling; and support the development of export markets for material substitutes and alternatives, including high-quality recycled plastics
>
> **h.** Promote further research, development, and adoption of material substitutes that are less polluting to the ocean – particularly, explore the adoption of natural materials, marine by-products, and postharvest agricultural waste, which could help spur innovation, support a more circular economy, and develop new industrial capacities in developing countries
>
> **i.** Undertake continuous statistical work monitoring and measuring the flows of plastics and non-plastic feedstocks, as well as end-use products, to produce analyses that support policy action.

ANNEX 2

	Type	Feedstock/Products	HS Code
1	Natural fibres - dedicated crops	Casein	040490
2	Natural fibres - animal-based	Down	050510
3	Natural fibres - animal-based	Down	050590
4	Natural fibres - agricultural by-products	Snail poo/fish skin or residues	051191
5	Natural fibres - dedicated crops	Mushroom	070959
6	Natural fibres - dedicated crops	Mushroom	070959
7	Natural fibres - dedicated crops	Calabash hard shell	070993
8	Natural fibres - dedicated crops	Mushroom	071151
9	Natural fibres - dedicated crops	Mushroom	071159
10	Natural fibres - agricultural by-products	Nettles/vegetable waste/microbial cellulose/cel-lulose	071190
11	Natural fibres - dedicated crops	Mushroom	071231
12	Natural fibres - dedicated crops	Mushroom	071239
13	Natural fibres - agricultural by-products	Grape waste	081190
14	Natural fibres - agricultural by-products	Grape waste	081290
15	Natural fibres - products	Starch	110812
16	Natural fibres - products	Starch	110813
17	Natural fibres - products	Starch	110819
18	Natural fibres - products	Ground-nuts, shelled	120220
19	Natural fibres - agricultural by-products	Ray (mulch / straw)	120925
20	Natural fibres - agricultural by-products	Areca leaves/banana leaves or stem/pineapple leaves	140190
21	Natural fibres - dedicated crops	Seaweed (incl. brown and red algae)	121221
22	Natural fibres - dedicated crops	Seaweed (incl. brown and red algae)	121229
23	Natural fibres - agricultural by-products	Coconut/wheat husks/corn-based	121300
24	Natural fibres - agricultural by-products	Hay/White clover(mulch)	121490
25	Natural Fibres - plant/tree-based	Vegetable	130219
26	Natural fibres – products	Vegetable	130231
27	Natural fibres – products	Vegetable	130232
28	Natural fibres – products	Vegetable	130239
29	Natural Fibres - plant/tree-based	Bamboo	140110
30	Natural fibres - agricultural by-products	Areca leaves/banana leaves or stem/pineapple leaves	140190
31	Natural fibres - agricultural by-products	Cotton linters	140420
32	Natural fibres - dedicated crops	Calabash hard shell	140490
33	Natural fibres - agricultural by-products	Beeswax-coated cloth	152110
34	Natural fibres - agricultural by-products	Syrup	170230
35	Natural Fibres - plant/tree-based	Syrup	170260
36	Natural fibres - agricultural by-products	Bamboo shoots	200591
37	Natural fibres - agricultural by-products	Coconut/Wheat Husks/Corn-based	230240

	Type	Feedstock/Products	HS Code
38	Natural fibres - agricultural by-products	Tofu waste	230250
39	Natural fibres - agricultural by-products	Sugarcane - bagasse	230330
40	Natural fibres - plant/tree-based	Vegetable	230800
41	Minerals	Aluminium	281820
42	Minerals	Aluminium	281830
43	Natural fibres - agricultural by-products	Alcohols; polyhydric, d-glucitol (sorbitol)	290544
44	Natural fibres - agricultural by-products	Alcohols; polyhydric, glycerol	290545
45	Minerals	Glass	320740
46	Natural fibres - agricultural by-products	Cellulose	391239
47	Natural fibres - agricultural by-products	Cellulose	391290
48	Natural fibres - dedicated crops	Seaweed (incl. brown and red algae)	391310
49	Natural Fibres - plant/tree-based	Vegetable	391390
50	Natural Fibres - plant/tree-based prod-ucts	Cellulose	392079
51	Natural fibres - dedicated crops	Rubber	400110
52	Natural Fibres - plant/tree-based	Rubber	400121
53	Natural Fibres - plant/tree-based	Rubber	400122
54	Natural Fibres - plant/tree-based	Rubber	400129
55	Natural fibres - animal-based	Leather	410711
56	Natural fibres - animal-based	Leather	410712
57	Natural fibres - animal-based	Leather	410719
58	Natural fibres - animal-based	Leather	410790
59	Natural fibres - animal-based	Leather	410791
60	Natural fibres - animal-based	Leather	410792
61	Natural fibres - animal-based	Leather	410799
62	Natural fibres - animal-based	Leather	411200
63	Natural fibres - animal-based	Leather	411310
64	Natural fibres - animal-based	Leather	411320
65	Natural fibres - animal-based	Leather	411330
66	Natural fibres - animal-based	Leather	411390
67	Natural Fibres - plant/tree-based	Wood	440130
68	Natural Fibres - plant/tree-based	Bamboo	440210
69	Natural fibres - products	Finished cooler box	420292
70	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440311
71	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440312
72	Natural Fibres - plant/tree-based	Wood	440320
73	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440321
74	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440322

	Type	Feedstock/Products	HS Code
75	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440323
76	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440324
77	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440325
78	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440326
79	Natural Fibres - plant/tree-based	Wood	440331
80	Natural Fibres - plant/tree-based	Wood	440332
81	Natural Fibres - plant/tree-based	Wood	440333
82	Natural Fibres - plant/tree-based	Wood	440334
83	Natural Fibres - plant/tree-based	Wood	440335
84	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440341
85	Natural Fibres - plant/tree-based	Wood	440349
86	Natural Fibres - plant/tree-based	Wood bark (mulch/packaging)	440391
87	Natural Fibres - plant/tree-based	Wood	440392
88	Natural Fibres - plant/tree-based	Wood	440393
89	Natural Fibres - plant/tree-based	Wood	440394
90	Natural Fibres - plant/tree-based	Wood	440395
91	Natural Fibres - plant/tree-based	Wood	440396
92	Natural Fibres - plant/tree-based	Wood	440397
93	Natural Fibres - plant/tree-based	Wood	440398
94	Natural Fibres - plant/tree-based	Wood	440399
95	Natural Fibres - plant/tree-based	Woodchip (mulch/packaging/textiles)	440711
96	Natural Fibres - plant/tree-based	Woodchip (mulch/packaging/textiles)	440712
97	Natural Fibres - plant/tree-based	Woodchip (mulch/packaging/textiles)	440719
98	Natural Fibres - plant/tree-based	Woodchip (mulch/packaging/textiles)	440721
99	Natural Fibres - plant/tree-based	Balsa wood	440722
100	Natural Fibres - plant/tree-based	Woodchip (mulch/packaging/textiles)	440791
101	Natural Fibres - plant/tree-based	Woodchip (mulch/packaging/textiles)	440792
102	Natural Fibres - plant/tree-based	Woodchip (mulch/packaging/textiles)	440793
103	Natural Fibres - plant/tree-based	Bamboo	440921
104	Natural Fibres - plant/tree-based	Bamboo	441210
105	Natural Fibres - plant/tree-based	Bamboo	441873
106	Natural Fibres - plant/tree-based	Bamboo	441891
107	Natural Fibres - plant/tree-based	Bamboo	441911
108	Natural Fibres - plant/tree-based	Bamboo	441912
109	Natural Fibres - plant/tree-based	Bamboo	441919
110	Natural Fibres - plant/tree-based	Bamboo	442191
111	Natural Fibres - plant/tree-based	Cork	450110

	Type	Feedstock/Products	HS Code
112	Natural fibres - plant/tree-based	Cork	450190
113	Natural fibres - plant/tree-based	Cork	450200
114	Natural fibres - plant/tree-based	Cork	450310
115	Natural fibres - plant/tree-based	Cork	450390
116	Natural fibres - plant/tree-based	Cork	450410
117	Natural fibres - plant/tree-based	Cork	450490
118	Natural fibres - plant/tree-based products	Bamboo	460121
119	Natural fibres - plant/tree-based	Bamboo	460192
120	Natural fibres - products	Vegetable	460193
121	Natural fibres - products	Vegetable	460194
122	Natural fibres - products	Vegetable	460211
123	Natural fibres - products	Vegetable	460212
124	Natural fibres - products	Vegetable	460219
125	Natural fibres - products	Vegetable	460290
126	Natural fibres - plant/tree-based	Wood pulp	470100
127	Natural fibres - plant/tree-based	Wood pulp	470200
128	Natural fibres - plant/tree-based	Wood pulp	470311
129	Natural fibres - plant/tree-based	Wood pulp	470319
130	Natural fibres - plant/tree-based	Wood pulp	470321
131	Natural fibres - plant/tree-based	Wood pulp	470329
132	Natural fibres - plant/tree-based	Wood pulp	470411
133	Natural fibres - plant/tree-based	Wood pulp	470419
134	Natural fibres - plant/tree-based	Wood pulp	470421
135	Natural fibres - plant/tree-based	Wood pulp	470429
136	Natural fibres - plant/tree-based	Wood pulp	470500
137	Natural fibres - plant/tree-based	Wood pulp	470610
138	Natural fibres - plant/tree-based	Wood pulp	470620
139	Natural fibres - plant/tree-based	Wood pulp	470630
140	Natural fibres - plant/tree-based	Wood pulp	470691
141	Natural fibres - plant/tree-based	Wood pulp	470692
142	Natural fibres - plant/tree-based	Wood pulp	470693
143	Natural fibres - plant/tree-based	Paper	480261
144	Natural fibres - plant/tree-based	Paper	480262
145	Natural fibres - plant/tree-based	Paper	480269
146	Natural fibres - plant/tree-based	Paper	480411
147	Natural fibres - plant/tree-based	Paper	480419
148	Natural fibres - plant/tree-based	Paper	480451

	Type	Feedstock/Products	HS Code
149	Natural fibres - plant/tree-based	Paper	480511
150	Natural fibres - plant/tree-based	Paper	480512
151	Natural fibres - plant/tree-based	Paper	480519
152	Natural fibres - plant/tree-based	Paper	480591
153	Natural fibres - plant/tree-based	Paper	480592
154	Natural fibres - plant/tree-based	Paper	480593
155	Natural fibres - plant/tree-based	Paper	480840
156	Natural fibres - plant/tree-based	Paper	480890
157	Natural fibres - plant/tree-based	Paper	481160
158	Natural fibres - plant/tree-based	Paper	481190
159	Natural fibres - plant/tree-based	Paper	481200
160	Natural fibres - plant/tree-based products	Paper	481910
161	Natural fibres - plant/tree-based products	Paper	481920
162	Natural fibres - plant/tree-based products	Paper	481930
163	Natural fibres - plant/tree-based products	Paper	481940
164	Natural fibres - plant/tree-based products	Paper	481950
165	Natural fibres - plant/tree-based products	Paper	481960
166	Natural fibres - plant/tree-based products	Paper	482210
167	Natural fibres - plant/tree-based products	Paper	482290
168	Natural fibres - plant/tree-based products	Paper	482320
169	Natural fibres - plant/tree-based products	Paper	482340
170	Natural fibres - plant/tree-based products	Paper	482361
171	Natural fibres - plant/tree-based products	Paper	482369
172	Natural fibres - plant/tree-based products	Paper	482370
173	Natural fibres - plant/tree-based products	Paper	482390
174	Natural fibres - animal-based	Silk	500200
175	Natural fibres - animal-based	Silk	500300
176	Natural fibres - animal-based	Silk	500310
177	Natural fibres - animal-based	Silk	500390
178	Natural fibres - animal-based	Silk	500400
179	Natural fibres - animal-based	Silk	500500
180	Natural fibres - animal-based	Silk	500600
181	Natural fibres - animal-based	Silk	500710
182	Natural fibres - animal-based	Silk	500720
183	Natural fibres - animal-based	Silk	500790
184	Natural fibres - animal-based	Wool (mulch/pack./textile)	510111
185	Natural fibres - animal-based	Wool (mulch/pack./textile)	510119

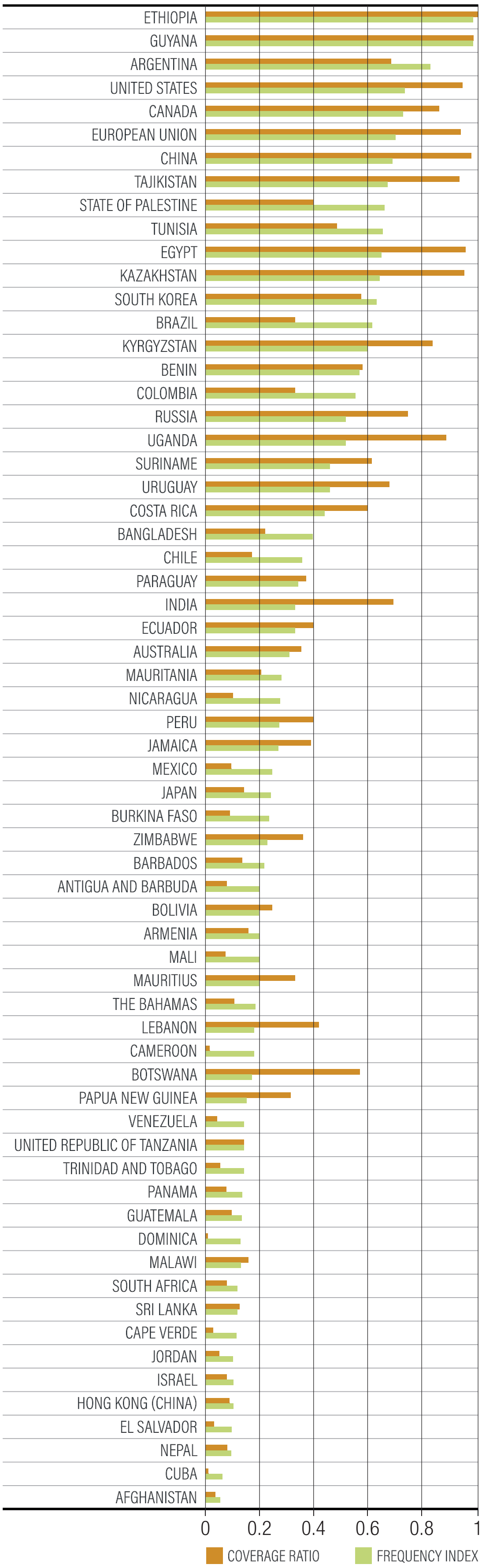
	Type	Feedstock/Products	HS Code
186	Natural fibres - animal-based	Wool (mulch/pack./textile)	510121
187	Natural fibres - animal-based	Wool (mulch/pack./textile)	510129
188	Natural fibres - animal-based	Wool	510130
189	Natural fibres - animal-based	Cashmere	510211
190	Natural fibres - animal-based	Cashmere	510219
191	Natural fibres - animal-based	Wool	510310
192	Natural fibres - animal-based	Wool	510320
193	Natural fibres - animal-based	Wool	510330
194	Natural fibres - animal-based	Wool	510400
195	Natural fibres - animal-based	Wool	510510
196	Natural fibres - animal-based	Wool	510521
197	Natural fibres - animal-based	Wool	510529
198	Natural fibres - animal-based	Cashmere	510531
199	Natural fibres - animal-based	Cashmere	510539
200	Natural fibres - animal-based	Wool	510540
201	Natural fibres - animal-based	Wool	510610
202	Natural fibres - animal-based	Wool	510620
203	Natural fibres - animal-based	Wool	510710
204	Natural fibres - animal-based	Wool	510720
205	Natural fibres - animal-based	Wool	510810
206	Natural fibres - animal-based	Wool	510820
207	Natural fibres - animal-based	Wool	510910
208	Natural fibres - animal-based	Wool	510990
209	Natural fibres - animal-based	Cotton	520100
210	Natural fibres - animal-based	Cotton	520300
211	Natural fibres - animal-based	Cotton	520420
212	Natural fibres - plant/tree-based	Flax	530110
213	Natural fibres - plant/tree-based	Flax	530121
214	Natural fibres - plant/tree-based	Flax	530129
215	Natural fibres - dedicated crops	Hemp	530210
216	Natural fibres - dedicated crops	Jute	530310
217	Natural fibres - dedicated crops	Jute	530390
218	Natural fibres - agricultural by-products	Coconut/abaca/wheat husks/corn-based	530500
219	Natural fibres - plant/tree-based	Flax	530610
220	Natural fibres - plant/tree-based	Flax	530620
221	Natural fibres - dedicated crops	Jute	530710
222	Natural fibres - dedicated crops	Jute	530720

	Type	Feedstock/Products	HS Code
223	Natural fibres - dedicated crops	Coir	530810
224	Natural fibres - dedicated crops	Hemp	530820
225	Natural fibres - dedicated crops	Vegetable	530890
226	Natural fibres - dedicated crops	Flax	530911
227	Natural fibres - dedicated crops	Flax	530919
228	Natural fibres - dedicated crops	Jute	531010
229	Natural fibres - dedicated crops	Jute	531090
230	Natural fibres - dedicated crops	Vegetable	531100
231	Natural fibres - products	Viscose rayon	540310
232	Natural fibres - products	Viscose rayon	540331
233	Natural fibres - products	Viscose rayon	540332
234	Natural fibres - products	Viscose rayon	540341
235	Natural fibres - dedicated crops	Sisal	560721
236	ALDFG - natural fibres	Ropes and cables	560729
237	ALDFG - natural fibres	Ropes and cables	560790
238	ALDFG - natural fibres	Fishing nets	560890
239	Natural fibres - products	Nonwoven natural fibre insulation	570220
240	239 Natural fibres - products	Jute	630510
241	Natural fibres - products	Hemp/vegetable	630590
242	Natural fibres - animal-based	Down	670100
243	Mineral products	Ceramics	680422
244	Mineral products	Ceramics	690600
245	Mineral products	Ceramics	690990
246	Mineral products	Ceramics	691190
247	Mineral products	Ceramics	691200
248	Minerals	Glass	701010
249	Minerals	Glass	701090
250	Minerals	Glass	701911
251	Minerals	Glass	701912
252	Minerals	Glass	701919
253	Minerals	Glass	701940
254	Minerals	Glass	701951
255	Minerals	Glass	701952
256	Minerals	Glass	701959
257	Minerals	Aluminium	760110
258	Minerals	Aluminium	760120
259	Minerals	Aluminium	760310

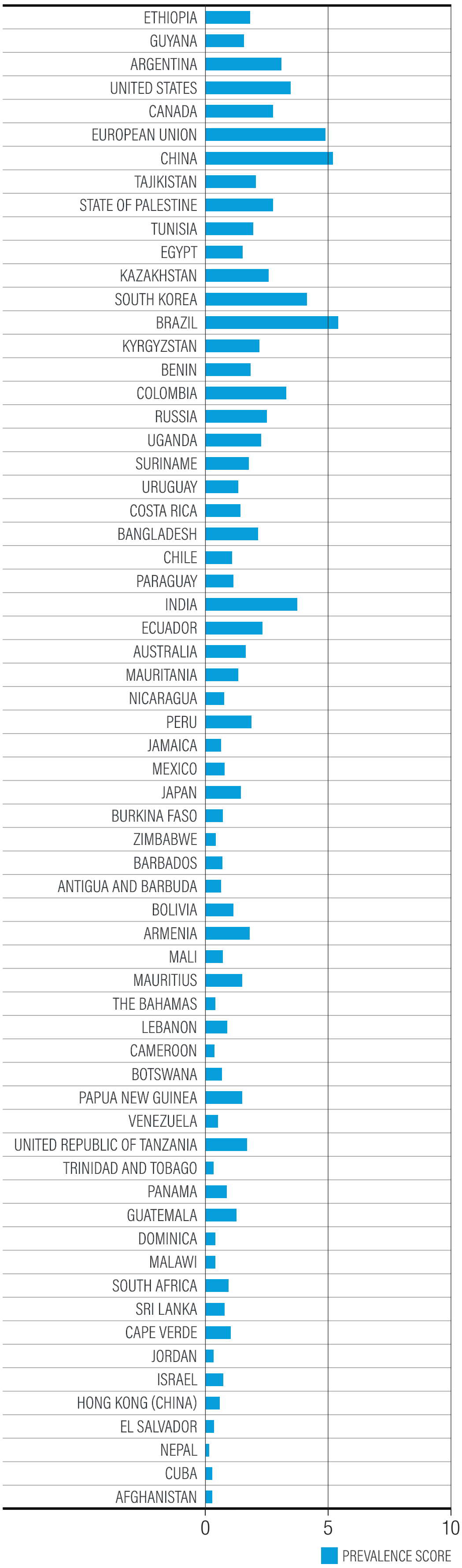
	Type	Feedstock/Products	HS Code
260	Minerals	Aluminium	760320
261	Minerals	Aluminium	760421
262	Minerals	Aluminium	760429
263	Minerals products	Aluminium	760611
264	Minerals products	Aluminium	760612
265	Minerals products	Aluminium	760691
266	Minerals products	Aluminium	760692
267	Minerals products	Aluminium	760711
268	Minerals products	Aluminium	760719
269	Minerals products	Aluminium	760720
270	Minerals products	Aluminium	761210
271	Minerals products	Aluminium	761290
272	Minerals products	Aluminium	761300
273	Minerals products	Aluminium	761510
274	Natural fibres - products	Bamboo	940152
275	Natural fibres - products	Rattan	940153
276	Natural fibres - products	Bamboo	940382
277	Natural fibres - products	Rattan	940383
278	ALDFG - other	Fishing rod	950710
279	ALDFG - other	Fishing hooks	950720
280	ALDFG - other	Fishing reel	950730
281	ALDFG - other	Fishing tackle	950790
282	Minerals products	Worked vegetable or mineral carving material; wax/stearin/natural gums or resins/pastes/unhardened gelatin	960200

ANNEX 3

Coverage ratio and frequency index import measures



Prevalence score import measures



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