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Review

'Unlocking circular economy for prevention of marine plastic pollution: An exploration of G20 policy and initiatives'

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ABSTRACT

Marine plastic pollution (MPP) is an urgent environmental and socio-economic problem. MPP amounts to 300 million tons annually, originates largely from land-based sources and severely impacts marine ecosystem, harms livelihoods and causes costs for businesses and governments. Plastics permeate the whole width and depth of seas and oceans, near well-developed coastal zones and equally in remotest corners. This undermines economic and social value of the oceans, particularly in terms of fisheries productivity and tourism. The G20 members, responsible for about two-thirds of global plastic waste, recognize the problem and undertake preventive measures – individually and collectively. Yet, are there efficient, effective and sufficient given the urgency of MPP and the contribution of G20 countries. This article highlights existing policies and identifies further policy options using a custom framework for MPP policy that merges Circular Economy (CE) and life-cycle perspectives.

1. Introduction

The international community has recognized marine plastic pollution (MPP)[2] as an important impediment for sustainable development (UNEP, 2016). Mismanaged plastic waste largely ends up in oceans, either directly, from sources at sea, or indirectly, from sources on land, through littering from shores, run-off from sewage systems, or by rivers and wind. Data suggest that plastic packaging represents the major share of this leakage. Annually, at least 8 million tonnes of plastics leak into the oceans — which is equivalent to dumping the contents of one garbage truck into the ocean every minute (Ellen MacArthur Foundation, 2017). If no action is taken, this is expected to double by 2030 and quadruple by 2050.

The 2030 Agenda for Sustainable Development has galvanized unanimous global commitment to address unsustainable plastic use and MPP. Sustainable Development Goal (SDG) 14, Life Below Water, urges to conserve and sustainably use the oceans, seas and marine resources for sustainable development. SDG target 14.1 specifically addresses marine litter: by 2025: prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. Moreover, SDGs 6 (water), 11 (cities) and 12 (sustainable consumption and production) are relevant to marine litter prevention.

United Nations Environment Programme (UNEP) prepared a global assessment report on marine plastic debris and microplastics. The key messages of prevention were considered and endorsed by the ad-hoc open-ended expert group, under United Nations Environment Assembly resolution 3/7 (UNEP/EA.3/Res.7) (UNEP, 2016). These messages were: (3) transition to a 6R circular plastic economy (Reduce, Redesign, Remove, Reuse, Recycle and Recover); (8) comprehensive approach to address leakage in all stages of production, use and disposal cycle; and (13) urgency to start with improved waste management, in particular in

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[2] MPP comprises both large objects and smaller fragments, down to micro-plastics, which remain largely invisible to the naked eye yet interfere most with marine life. Microplastics are routinely defined as small particles or fragments of plastic measuring less than 5 mm in diameter. Some microplastics are purposefully manufactured for industrial and domestic purposes ('*primary*' microplastics). These include '*microbeads*' used in cosmetic and personal healthcare products, such as toothpaste. '*Secondary*' microplastics are created by the weathering and fragmentation of larger plastic objects.

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Table 1
Principal waste prevention approaches for MPP in plastics value chain (Amended and updated from UNIDO, 2019).

Life Cycle Stage	Waste Prevention Approach	Application for prevention of MPP
Product Design	Design for Environment (DfE), Design for Sustainability or Sustainable Product Design (UNEP, 2009) includes environmental criteria in design of products and services and their associated packaging, distribution and service systems. DfE includes such practices as: functional redesign/new product or packaging concept; selection of renewable, recycled, recyclable and/or less harmful materials; reduction of material diversity; product life optimization; minimization of input requirements during use; and ease of repair, dismantling, recovery, recycling and environmentally sound disposal.	• DfE has been proven applicable to the main contributors to addressing MPP, namely: (1) short-lived plastic products (including packaging, utensils, personal care products, etc.); and (2) micro-plastics (from cosmetics and synthetic garments). •Adoption of DfE is largely hampered by: (1) lack of awareness of and capacity for DfE; (2) perceived superiority of single use products (w.r.t. convenience, food safety, etc.); (3) limited availability and/or (perceived) inferior quality of alternative materials, including bio-based and biodegradable plastics; and (4) unfavorable economics due to high cost of alternatives and low costs of waste disposal.
Manufacturing and Service Delivery	Resource Efficient and Cleaner Production (RECP): improves efficiency of use of materials, energy and water and reduces intensity of generation of waste, effluents and emissions in manufacturing and associated processing and service sectors. RECP is possible through such practices as: good housekeeping; input substitution; better operating practices; equipment modification; technology change; onsite recovery and reuse; production of useful by-products; and product modification (Van Berkel and Fadeeva, 2020).	•RECP has been proven applicable to prevent plastics waste generation from manufacturing, processing and service sectors and associated distribution and maintenance, including sectors most relevant to MPP, such as plastics manufacturing, packaging, hospitality, textile, accessories and cosmetics. •Adoption of RECP is principally hampered by: (1) lack of awareness of and capacity for RECP; (2) weak firm-level perceptions and practices of productivity and quality; and (3) unfavorable economics resulting from low plastic prices and low current costs of waste disposal.
Distribution and Use	Sustainable Consumption (SC): (UNEP, 2010) refers to use of services and products which enable better quality of life whilst minimizing impact on environment. This involves actions of individual consumers, institutional consumers (including government though its public procurement), and retail and service sectors.	•SC has proven its applicability for plastics packaging and products that contribute significantly to MPP challenge, through focused activities on short-lived products. •Implementation of SC is in the main impeded by: (1) a lack of consumer information and awareness on SC alternatives: (2) prevailing littering practices; (3) insufficient infrastructure support for SC alternatives; and (4) unfavorable economics resulting from low cost of short-lived plastic products and low current costs of waste disposal.
End-of-Life Management	Environmentally Sound Waste Management and Resource Recovery: systems for comprehensive (*'leakage free'*) collection, sorting, cleaning and processing of all end of life plastic products and packaging, into secondary resources	•Best Available Techniques/Best Environmental Practices (BAT/BEP) have been demonstrated for disposal of plastic products and packaging and microplastics, in manner that reduces MPP. •BAT/BEP uptake is impeded by: (1) prevailing attitudes and associated littering and waste disposal practices leading to low quality plastic waste; (2) unfavorable economics due to costs of processing (and subsequently of secondary materials) relative to costs of environmentally unsound waste disposal and of virgin materials; and (3) high informality in waste management and recycling sectors, in particular in LDCs/MICs

developing countries.

The G20 countries generate an estimated two-thirds of global plastic waste, China, US and Germany being the top producers. Seven of the ten major rivers that carry land plastic pollution to the oceans enter the oceans from China, India and Indonesia (Schmidt et al., 2017). This highlights the importance of G20 members to lead abatement of marine litter, particularly plastics.

In its 2017 Action Plan on Marine Litter, G20 recognized "*the urgent need for action to prevent and reduce marine litter in order to preserve human health and marine and coastal ecosystems, and mitigate marine litter's economic costs and impacts*" (OECD, 2019). In the 2019 Osaka Summit outcome document (G20 Osaka Leaders Declaration, 2019), G20 leaders "*reiterate that measures to address marine litter, especially MPP and microplastics, need to be taken nationally and internationally by all countries in partnership with relevant stakeholders. In this regard, we are determined to swiftly take appropriate national actions for the prevention and significant reduction of discharges of plastic litter and microplastics to the oceans*". And: "*we share …. as a common global vision, the "Osaka Blue Ocean Vision" that we aim to reduce additional pollution by marine plastic litter to zero by 2050 through a comprehensive life-cycle approach that includes reducing the discharge of mismanaged plastic litter by improved waste management and innovative solutions while recognizing the important role of plastics for society*". This was further operationalized with the endorsement of the G20 Implementation Framework for Actions on Marine Plastic Litter, which has as its main components: facilitation by information sharing on implementation of actions and developments therein, and collaborative action and outreach beyond G20 in regard to promotion of international cooperation, innovative solutions, scientific information and knowledge and multi-stakeholder involvement and awareness raising (MOFA, 2019).

Both the G20 process and UNEP Global Assessment stress importance of Circular Economy (CE) to curb MPP. Hence, we set out to connect policy initiatives of G20 Members to the CE framework. Therefore, we first review - in brief – the plastics life cycle, and operationalize therein key CE elements. Next, we map the current policy instruments that impact MPP, and illustrate these with examples from G20 countries against the CE elements. We observe therein that current policy instruments appear insufficient by intent and/or current operationalization to achieve the desired circular plastics transition for abating MPP. The new framework may serve as lens for strengthening policy for and practice of MPP abatement.

2. Marine Plastic pollution – circular economy perspective

2.1. Plastics life cycle

Plastics escape at any stage from economic system and are then carried to oceans where it ultimately shows up as MPP. Addressing MPP, hence, requires concerted actions throughout plastics' life-cycles, driven by consistent government policies and enabled by effective waste collection, management and recycling sector. Table 1 highlights such key actions and overall illustrates that good practices and techniques exist and have been demonstrated for – precursors of – MPP. However, these are not yet common place, for a variety of reasons, particularly related to prevailing behaviors of consumers, producers, retailers and waste managers, and – perceived and/or actual – unfavorable economics of alternatives to plastics, in particular in short-lived products. Economics, awareness and behavior though are also a reflection of the current status of policy, particularly for waste management and/or deficiencies in their implementation and enforcement.

2.2. Circular economy

Circular Economy (CE) provides focus springboard to ascertain the

efficacy and efficiency of existing MPP policies. This provides further impetus to sharpen and refine the spectrum of policies and their implementation, monitoring and enforcement.

CE stresses the need for the perpetuality, circularity and shift from the notion of waste to the notion of secondary materials. It denounces the prevailing linear '*extract-make-use-throw*' economy and elevates the need for restorative and regenerative '*extract-make-use-recover and restore*' economy. The Ellen MacArthur Foundation (2012) explains CE through the concepts of eco-efficiency and eco-effectiveness to minimize of material and energy flows through the system, generate 'cradle--to-cradle' metabolism and retain previously wasted materials as a resource. CE aims at keeping value of materials, products and their parts at all times high. The model is based on two cycles – technical and biological where consumption *"happens only in biological cycles, where nutrients are metabolized – e.g. through composting or anaerobic digestion – and life processes regenerate the living systems, such as soil, plants, or animals, that give rise to materials and other resources. Technical cycles recover and restore products, components, and materials through strategies like reuse, repair, remanufacture, refurbishment, or (in the last resort) recycling*" (Ellen MacArthur Foundation, 2016). As mainstream plastics (with biobased polymers being the only exception) are made from and with non-renewable fossil material and fuel, they are technical materials and from a CE perspective are to be retained in technical cycles through production, consumption and resource recovery systems.

As illustrated in Box 1, we earlier operationalized CE for industry and business (Van Berkel and Fadeeva, 2020), into a three-pronged approach for: *resource switch* - maximizing renewables and non-harmful inputs; *resource efficiency* - relentlessly practicing efficiency in design, production and use; and *resource circularity* - perpetual recovery and reuse of end of life materials. The main waste prevention practices highlighted in Table 1, contribute to these three elements. DfE in the main addresses the resource switch, yet the product design itself will enable efficiency and circularity. RECP is predominantly concerned with efficiency, and, to a lesser extent resource switch and circularity. Both SC and waste management primarily practice circularity, though also more indirectly contribute to resource efficiency and switch.

3. Mapping the policy space

Government policy would need to discourage and ultimately eliminate indiscriminate and environmentally harmful disposal and burning, whilst encouraging the use of quality recycled materials and fostering innovation (in products, technologies, business models, lifestyle and consumption patterns) (Van Berkel, 2018). Toward this, we have noted the stated global priority for litter and pollution prevention and abundance of prevention options through improvements in production and consumption systems and associated waste management and resource recovery. MPP prevention can thus start with policies for wider and more focused application of known good practices, through consistent policy and implementation, in collaboration with consumers, producers, farmers and other waste generators and formal and informal waste management sectors (covering collection, recycling, recovery and environmentally sound disposal). Responsible behavior by all partners along with business-like methods and systems are necessary.

MPP policy would need to cover all CE elements as well as all life cycle stages. As illustrated in Fig. 1, this requires policies to address materials extraction and selection; product design; product manufacturing and distribution; consumption and disposal; and end of life management. Some policy instruments can be specific to plastics, or even specific types of plastics and/or their additives, whereas others may have a more generic scope. In Table 2 policy instruments have been mapped against the CE elements, namely resource switch, efficiency and circularity. This is bound to some limitations, as the actual impact of a policy instrument depends, to a large extent, on its detailed design and efforts towards implementation, monitoring and enforcement. Nevertheless, as a preliminary observation, among the three CE elements, circularity is the most specifically targeted by the currently practiced set of policy instruments. This could reflect the necessity to deal with the environment and associated community health impacts of waste disposal. On the other hand, efficiency appears to be not vigorously addressed, except through resource efficiency/cleaner production programmes which are most typically based on information, training and advisory services. This may reflect the common perception that efficiency does have its own economic rationale of cost savings and hence does not require focused policy interventions. The input/resource switch related instruments, both for encouraging preferred as well as for discouraging undesired materials and applications, are conceptually well-developed and mutually reinforcing, yet, so far only deployed for rather narrow categories of materials and products, in view of the economic interests. Overall, no single policy instrument will be able to trigger a comprehensive reorientation towards CE, apart from the newly emerging CE packages, which in their own right contain a mix of policy instruments. Furthermore, there is scope for more general-purpose enabling policies, such as knowledge development, innovation, etc., which will be addressed in section 5.

4. Empirical Illustrations

We turn to G20 to explore the current state of development and deployment of MPP prevention policy. This is based on initiatives of each of the G20 members by mid-2019 as documented in the public domain. While this analysis illustrates trends and issues, given the dynamic development of MPP policy and actions at national, regional and global levels, it cannot be taken as a comprehensive and detailed policy assessment or seen as a cross-national comparison.

4.1. Discouraging input of undesirable materials and products

Most G20 members have adopted laws and regulations that prevent market access of specific single-use plastic products or products containing and/or causing microplastics. The measures include total ban, discouragement (levy based) and encouragement (through information and communication only), and combinations thereof. This provides a strong incentive for product alternatives that allow for easy sorting and recycling and/or make the product more environmentally benign and less harmful to health. Overall, the countries aim to close the '*front door*' for undesired plastic applications, thereby encourage design alternatives (alternative products and packaging) and material alternatives (products made from preferred material).

Ban on single-use plastics has become well-established approach with initial bans for individual products evolving over time into more complex strategies. The *European Commission* (2019) works to operationalize its Single Use Plastics Directive, initially tabled in May 2018. It targets ten single-use plastic items, commonly found on European beaches, that represent about half of MPP. Many G20 members combine banning free plastic bags or other single-use plastic products with measures facilitating change towards alternatives with different properties – durability, recyclability, recycled contents, biodegradability – either in plastic or of paper, jute, etc.. In *China*, retailers are discouraged to use plastic bags made from materials that are not biodegradable. With subsidies from the government, farmers in China have to use degradable plastic films for agricultural use (Tze Yan, 2018).

Life-cycle perspective accompanies bans in some G20 countries. Some states in *India* moved to enforce rules against manufacturing and using some single-use plastics (Dasgupta, 2019). The new Packaging Act of *Germany* (2019) addresses plastics life-cycle to reduce end-of-life plastics. By stipulating that – plastic - packaging, has to be designed with recyclability in mind (VERPACKG, 2019), it provides for improvement (including simplification) of the collection and sorting systems.

France is introducing a penalty system to discourage the use of non-recycled plastics for packaging – up to 10 percent of the product's price

Box 1
Operationalization of Circular Economy (Adapted from Van Berkel and Fadeeva, 2020)

1. *Resource Switch: Go for renewable and eliminate harmful inputs* – maximization of use of renewable materials and energy as well as elimination of input of harmful materials into supply chains of products and services.
2. *Resource Circularity: Close the loop through perpetual recovery and reuse* –extending, to the maximum, 'life' of the materials in the system including by utilizing discarded materials as a secondary resource. Closing the loop requires differentiation between biological and technical cycles where biological cycles fed materials back into the system and technical cycles recapture, recover and restore value of products, components and materials.
3. *Resource Efficiency: Do more with less* – minimization of intensity of use of natural, non-renewable, materials and energy.

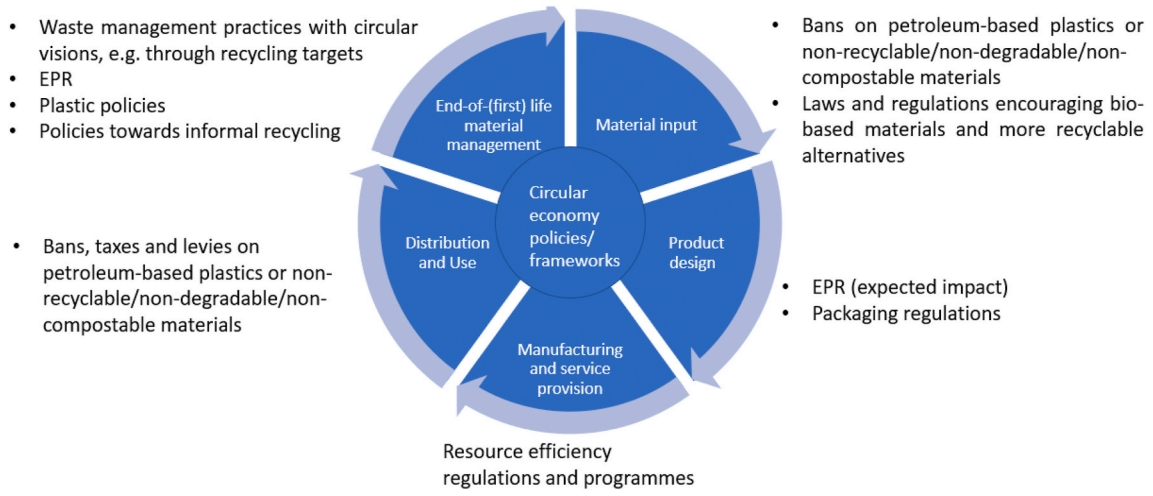

Fig. 1. Policies for facilitating circular plastics.

Table 2
Contribution of policy instruments into elements of Circular Economy.

Policy instruments	*Circular Economy Element*			
	Resource Switch		Resource Circularity	Resource Efficiency
	Discourage input of undesirable materials and products	Encourage input of preferred materials and products	Circularity - facilitate recovery of materials for subsequent application	Achieve more efficient use of materials in production and consumption systems
Stimuli for environmentally preferred/ friendly materials, e.g., bio-based		***	*	*
Ban on undesirable materials or material applications	***		**	
Resource efficiency policies and programmes		*	*	***
Waste laws and regulations (with focus on recycling)	*	*	***	
Packaging regulations	**	**	***	
Extended Producer Responsibility (EPR)	*		*	
Plastic regulations	***	***	*	
Regulations with regards to formalization of the waste management sector			***	
Circular economy promotion packages	*	**	***	

(***) intended outcome, (**) significant contribution; (*) positive correlation.

would be subtracted or added to the VAT, if it is made of non-recycled plastic (Rush, 2018). Moreover, pilots for a deposit system are underway in different regions. These complement the ban on single-use plastics adopted in 2016, which comes into full effect in 2020. Measures have been prepared to ban plastic straws and stirrers, cups and food containers under the country's sustainable food initiative (Government of France, 2018). *Mexico*, through additions to the Waste Law of the Federal District, aims at reduction of single-use plastic bags through imposing levies on consumer packaging and products. Provisions also include measures to advance use of durable bags for multiple use, or other, more environmentally preferred, bags (Jiménez Martínez, 2015). In the *UK*, a tax has been imposed on virgin plastic (Hirsh, 2019), which has upped the demand for recycled plastics, thereby facilitating the recovery of plastic wastes into the production-consumption cycle.

Notably, local authorities in several countries, such as Australia (Smith, 2020), Brazil (Global Site Plans, 2019), Canada, Italy (Xin Huan

Table 3
National restrictions on use of microbeads (source: UNIDO, 2019).

Government of France, 2018	Ban on the sale, manufacture and import of rinse-off products
Canada, 2018	Ban on products with microbeads less than 5 mm in size
UK, 2018	Ban on plastic microbeads in cosmetics and personal care products
Italy	Draft legislation to ban microbeads in rinse-off cosmetics from 2020
India	Ban on microbeads to enter into force in 2020
South Africa	Microbeads ban has been proposed
United States of America	Federal ban on manufacture and sale of rinse-off cosmetics containing intentionally-added plastic microbeads, 2015; as of October 2015, all states, except California, banned plastic microbeads but allow biodegradable ones. The state of California ban does not allow even biodegradable microbeads.

Net, 2018), Indonesia (Break Free from Plastic, 2020) and Mexico (UNEP, 2018), have taken on more ambitious strategies and targets than their national counterparts, particularly for banning various single-use plastic products.

A number of countries have also moved towards bans on microbeads (see Table 3), particularly in personal care products, with some differentiation, as in the different states of USA, between biodegradable and non-biodegradable materials.

4.2. Encouraging input of preferred materials and products

Demand for new and different plastic materials comes with requirements of a clear classification system enabling producers, consumers and recyclers to make verifiable informed choices. The Government of *France* launched a recycled plastic initiative in 2019 (Rush, 2018), which includes a stipulation to indicate if the packaging is made from recycled plastic or is recyclable. The French law on energy transition and green growth differentiates between biobased, biodegradable/compostable plastics and oxo-fragmentable plastics (which generates microplastics), and prohibits the latter (European Bioplastics, 2015). *South Africa* plans to support establishment of recycling infrastructure and an accompanying compulsory specification for plastic bags and measures for their compliance and enforcement (Environment, 2017). In 2016 recyclability has become a focus in *Saudi Arabia* that issued a regulation requiring certain plastics - produced domestically or imported - to be made of approved and certified oxo-degradable material (SASO, 2016).

The success of any new product though relies heavily on its ability to meet quality and market expectations *Australia* has seen non fossil–based plastics enter the market, yet further standards and systems are required to verify and label plastics to biodegrade and compost. (Australasian Bioplastics Association, 2019).

Although bioplastics have a very low market share many G20 members actively encourage its development[3]. Some countries state substitution of fossil feedstock with bio-feedstock for plastic production as their policy goals. For example, in 2018, *Japan* announced its commitment to introduce 50 times the current amount of animal and plant-derived biomass plastic by 2030. The Draft New Plan for a Sound Material-Cycle Society states, as one of the goals, replacement of fossil-fuel based plastics with bioplastics while improving its practicality in use (Inoue, 2018).

Some countries have taken action to facilitate investments in the bioeconomy that could benefit, among others, bioplastic. Policies in *Brazil (OECD 2013)*, from the 1990s, have created a self-sustaining market of ethanol produced from agricultural crops and facilitated investments in bioplastics production. The Strategic Plan for the Sugar-Energy Industry (2012) introduced measures, including credits and government financing, and accompanying measures for financing renovation of sugarcane farms and cultivated areas, added to the generation of material for bioplastics. A number of research institutes, including one of the largest research facilities - the Institute for Technological Research (IPT) - supported research in bioplastics in Brazil. The São Paulo Research Foundation (FAPESP) supported, for decades, scientific and technological research for plastics produced from renewable materials.

Even the G20 members that do not – yet - have specific policies for production of bioplastics, see their research and technology institutions work on new, more environmentally benign materials. n. For example, in *Canada,* NRC Industrial Materials Institute in Boucherville, QC; the École Polytechnique in Montréal; and the University of British Columbia in Vancouver (Nay, 2014). Notably, research by public and private institutions has developed competitive technologies for production of bioplastics from locally available bio-resources, such as bioplastic made from starch material and pits discarded from the production of olive oil in *Turkey (Ozdamar and Ates 2018), (Mlalila* et al. *2018), (Barrett 2019)* and cassava in *Indonesia (Avani 2019)*.

4.3. Facilitating recovery of materials for subsequent application

4.3.1. Packaging regulations

As packaging is the single largest user of plastics (Ellen MacArthur Foundation, 2017), plastic waste management, littering and MPP are frequently addressed through packaging regulations. Packaging regulations typically aim to strike a balance between multiple objectives, including food/product safety, weight and volume of packaging relative to packaged product, and the resultant packaging waste.

The policy measures often specify desirable qualities of plastic packaging, e.g., recyclable or compostable, and impose differentiated fees for non-desirable, e.g., non-sortable or non-recyclable, packaging materials. This is typically stipulated along with timetabled objective for realization, including, potentially, recovery and recycling targets for post-consumer packaging waste recovery. In *Australia*, by 2025, 100 percent of packaging should be recyclable, compostable or reusable. The Australian Packaging Covenant Organisation (Government of Australia, 2018), with its 950 member companies and other stakeholders spearheads implementation with Packaging Sustainability Guidelines and measurable targets (APCO, 2019). Its Strategic Plan 2017–2022 focuses on improving resource efficiency through packaging design and other measures such as consumer education, labelling, research and sharing of knowledge. The 2019 Packaging Act of *Germany* requires the recycling rate for plastic packaging to be increased from 36 percent today to 63 percent by 2022. *France* initiated a "National Pact on Plastic Packaging" in February 2019 that stipulates manufacturers and distributors of consumer goods to reach 60 percent of recyclable plastic by 2022, reaching 100 percent recyclability or compostability by 2025 (Gvernment of France, 2019).

Economic incentives have become an integral part of facilitation strategies. In *Italy*, for example, CONAI scheme for industrial packaging, applies a high fee to non-sortable and non-recyclable packaging and no fee to reusables (Italian Good News, 2017).

Following the success of Germany's 1991 Packaging Ordinance, countries have brought packaging waste under extended producer responsibility (EPR). However, even though EPR principles are commonly referenced in packaging regulations, in several countries EPR is not (yet) fully operationalized in particular for post-consumer packaging waste. In 2016, a New Comprehensive Packaging Waste Management Bill was proposed to the *Argentina's* Chamber of Deputies together with a number of other bills relevant for circular management of plastics. The Bill,

[3] The term 'bioplastic' indicates the nature of input materials – biological instead of petroleum-based. It does not automatically mean biodegradable or additive-free. While there are some serious criticisms of bio-based plastics, they are viewed positively in the area of climate change because of the avoidance of fossil fuel input into their core material.

based on EPR principles, will require producers, packagers, importers and manufacturers of packaging materials to set up and finance a packaging waste management system (Beveridge & Diamond PC, 2016). The *Canadian* Council of Ministers of the Environment (CCME) has developed a strategy, built on the Canada-wide Action Plan for EPR, to reduce packaging waste and promote more sustainable packaging choices (CCME, 2019).

4.3.2. Extended producer responsibility

Analysis of waste management practices as well as practices related to materials and products, demonstrate that the bigger economies of today (and most of the G20 members) have operationalized – elements of - EPRs. Many countries apply EPR to packaging, by mandating quality of packaging materials and assigning responsibilities for financing end-of-life management of plastic products. EPR is generally accepted by stakeholders as a good practice that incentivizes producers to improve end-of-life product management and achieve higher material recovery across the product life cycle with great efficiency. Including mandatory recycling targets in EPR requirements adds to their effectiveness. Government oversight over EPR systems is critical to assure a level playing field among producers and avoid 'race to the bottom', wherein producer responsibility organizations (PROs) manipulate data to show compliance on paper only.[4]

4.3.3. Driving circularity through waste management rules

Waste management regulations are aimed at reducing leakage (or littering) of waste and of discouraging inappropriate final disposal and burning – each of these directs end-of-life material flows towards circularity, particularly with mandatory source segregation and recovery (or diversion) targets.

Reducing waste leakage o from production and consumption, through appropriate and controlled waste management remains a priority for several G20 members. New waste management policies aim to ban illegal dumping and introduce planned waste management, predominantly in the cities. The waste-related goal of the PROMARNAT (SEMARNAT, 2013) environmental plan of *Mexico* was reduction of uncontrolled disposal from 30 percent in 2013 to 17 percent in 2018. In 2010, *Brazil* adopted its progressive National Solid Waste Policy (2010), which mandates the preparation of solid waste plans by municipalities, closure of dump sites, increase in recycling (up to 45 percent), increase in waste-to-energy production and social inclusion of waste pickers (IBRD and World Bank, 2018).

Mandatory source segregation and recovery targets drive improvements in waste policy. In *China*, the target of 35 percent recycling of household waste is expected to be achieved by 2020. Forty-six major cities have developed facilities for sorting, collecting, transporting and treating waste, with some of them issuing local regulations for waste classification. The core Programme on Prevention of Waste in *France* aims at reduction of all household and commercial waste by 7 percent per capita in 2020 (Government of France, 2014) with plastics seen as the second highest priority in this group of waste materials. *Russia* focuses on recycling in waste management through the "On Waste from Production and Consumption" law (Government of Russian Federation, 2018) and the upcoming disposal ban for untreated/unsorted waste. The Recycling Enterprise Support Programme (RESP) of *South Africa* under the National Waste Management Strategy provides funds for projects and startups for buy-back centres, material recovery facilities, construction and demolition solutions as well as plastic palletization plants (DAFF, 2018). Separation of municipal waste in *Japan* - mandated according to specific waste fractions - is supported by information activities by local governments and financial support for upgrading domestic recycling, with subsidies for the new facilities. The budget for it grew from $4 million in 2017 to $15 million in 2018. In the same year, Japan set up a target for reducing use of single-use plastics to 25 percent and 60 percent recycling target for plastic containers by 2030, partially through incineration and energy recovery (Mainichi Japan, 2018).

4.3.4. Plastic policies

In their attempts to address marine plastic pollution, many G20 members have developed a range of policy measures related directly to plastic materials or products to facilitate circularity of plastics. Much effort is devoted to creating favorable conditions for plastics recycling, including development of recycling infrastructure, extracting additional value of plastic waste or elimination of materials that present challenges in recycling. For example, the Recycled Plastic Initiative of *France* (Rush, 2018) includes reduced VAT rate on recycling operations, increased landfill taxes, simplified collection system (through uniform colors for waste bags), introduction of a label (by 2020) to indicate nature of material, i.e., recycled and/or recyclable. In November 2018, *Canada* released its national Strategy of Zero Plastic Waste, with ongoing work on the Action Plan, which states the goals of prevention and recycling commensurate with CE philosophy. In *India*, the Plastic Waste and Management Rules (2016) apply to every waste generator, local body, Gram Panchayat (village council), manufacturer, importer and producer, and are framed to govern recycling and to phase out undesirable plastic materials. *Republic of Korea* undertook measures to upgrade recycling facilities and help to efficiently recycle or compost more types of plastic material in addition to PET plastic (Vink 2914). In 2018, the *UK* launched the 25 Year Environment Plan that aims at elimination of avoidable plastic waste by 2042, and announced a new strategy that refers to circularity and puts greater responsibility on businesses for addressing waste challenges (DEFRA, 2018).

Some countries take a broader perspective for plastics policy. *Germany's* Federal Ministry for the Environment, Nature Conservation and Nuclear Safety explicitly states closing of the material loop as a prerequisite for sustainable plastic use. It has set up a dialogue along the entire production chain focusing on the use of secondary raw materials. In 2018, the Ministry unveiled a plan for addressing plastic pollution based on five strategies (Deutsche Welle, 2020): 1. Avoiding unnecessary products and packaging, 2. Making packaging and other products more environmentally sound, 3. Creating more recycling, 4. Preventing plastic getting into organic waste, and 5. Supporting international cooperation for clean-up of the world's most polluted rivers.

A few G20 members specifically focus on plastic pollution in the marine environment. In 2018, *France* announced the creation of the "Oceans Mission" to deal with chemicals and plastics pollution of oceans and coral reef (Government of France, 2018). The *German* national program has a series of measures to implement the EU Marine Strategy Framework Directive (MSFD) and the Round Table on ship-generated waste (including plastic waste) (Round table marine litter 2017). *Indonesia* forms a Plan of Action on Marine Plastic Debris (2017–2025), based on 3R principle, that would focus on behavioral change and reduction of land-based leakage (Government of the Republic of Indonesia, 2017).

G20 members also adopt collective actions. The United States, Italy, Japan, Canada, Germany, France and the United Kingdom signed the Ocean Plastics Charter at the G7 meeting in Halifax (G7, 2018). It contains a commitment to reach 100 percent reusable, recyclable, or, where viable alternatives do not exist, recoverable plastics by 2030.

4.3.5. Policies and actions towards informal waste sector

Informal sector, significant in G20 countries across a range of economic activities, also plays a role in closing the materials cycle. According to estimates, informal waste collectors are responsible for 17–35 percent of municipal recycling in urban China (Steuer et al., 2018) and nearly all recycling in Saudi Arabia (Abdul-Sattar, 2019). The informal waste sector of South Africa employs two or three times more people than formal waste management (Arnold, 2018). About 1 percent of

[4] Focus group discussions with major beverage producers in India, March 2019.

urban dwellers in India are reportedly involved in informal waste collection and recycling (GIZ, 2010). National and sub-national governments have paid closer attention to inclusion of informal waste collectors, aggregators and recyclers as in their efforts to improve waste management practices.

Mexico City recognizes the role of the informal waste pickers (Wiego, 2016) and 'volunteer workers' in the waste management system (SEDEMA), and so does *Buenos Aires*. In 2002, the city withdrew the law that earlier made litter picking illegal (Balch, 2016), accepting informal recyclers as legitimate contributors to waste management. It gave formal status to a number of waste pickers grouped in 12 cooperatives and some separation activities are taking place in the state-run 'green centres'. Yet, the challenge remains as the total number waste pickers is twice as large (Gutman, 2018). Similarly, *Brazil* (Lima and Mancini, 2017), sees waste picking as a legitimate activity and waste pickers as stakeholders with a voice at the local, state, and national levels. Its Integrated Solid Waste and Carbon Finance Project (World Bank, 2018) includes specific strategies for integrating waste pickers into local waste management, for example through organization of waste pickers into cooperatives, e.g., CEMPRE (Brazilian Business Commitment for Recycling) (Cempre, 2020). Some initiatives aim at adding value to the activities of waste pickers by enabling them to create products from the collected waste. For example, the Clean Urban Delta Initiative provides a low-cost plastic shredder and molding machine to waste pickers in Rio de Janeiro so that they can make plastic statues and other souvenirs for tourists (Lacey, 2018).

In *India*, extended producer responsibility organizations (EPROs) work to provide incentives for the informal sector to formalize particularly for collection of plastics and electronic waste (GIZGIZ, 2010) - They do this, for example, by assisting with paying necessary administrative fees and making sure that such actions do not jeopardize earnings of the waste pickers, or by encouraging them to limit their actions to operations that are safe (in case of Waste Electronic and Electrical Equipment (WEEE)) (Singhal, 2019). The Department of Environmental Affairs in *South Africa* is developed guidelines to include the informal sector into the waste economy (Arnold, 2018) and initiatives like GreenCape's Greater Tygerberg Picker Project assist waste pickers to establish micro-enterprises.

4.4. Achieving more efficient use of materials in production and consumption

Plastic industry broadly employs modern manufacturing practices to achieve productivity and minimize material and energy losses through design and planning, new plastics machinery, mobile technology and internet services, which may be further enhanced by transition to Industry 4.0. National and international support of resource efficiency measures have been provided through a number of initiatives, including the flagship UNIDO/UNEP National Cleaner Production Centres (UNIDO, 2015). However, the proof of concept and practices of plastics waste minimization in various countries by the pioneering companies does not appear to automatically lead to a widespread uptake of the such practices by a broader range of industry and service sector, especially by small and medium size enterprises (SMEs) (Van Berkel, 2018).

Some G20 members have ambitious cleaner production policy measures or programmes promoting sustainable consumption and production (SCP) aiming at doing more and better with less material and energy inputs. CE Promotion Law of *China* is a foundation for resource efficiency along with a number of other regulations including Cleaner Production Promotion Law (adopted in 2002 and amended in 2012) (People's Republic of China, 2007). The Strategy on Resource Efficiency formulated in 2017 by NITI Aayog (2017) in *India* suggests a framework for enhancing resource-use efficiency in the Indian economy and industry. The recently published Draft Resource Efficiency Policy (Government of India, 2019) emphasises the importance of market-based instruments as well as command and control in changing attitude towards wastage of material and energy along all life cycle of materials. European Union and India Resource Efficiency Initiative (EU-REI) (REI-EU, 2017) is a project aimed at supporting India in implementing the SCP agenda that deals with resource recovery (e-waste, plastics and packaging) while facilitating collaboration between Indian and European businesses around issues of resource efficiency.

4.5. Circular approaches

Specific CE initiatives in some G20 countries provide coherent policies to perpetuate circulation of material and energy in their economies and foster efficiency of their use while focusing on an increase of renewable inputs. They address several stages of life-cycle – from design to return to the production-consumption cycles, and comprise a variety of laws, regulations and programmes.

The Law for CE Promotion of, passed by *China* (Standing Committee of the National People's Congress, 2008), has become a reference point for circular initiatives. The 13th 'Five Year Plan' (2016–2020) (NDRC, 2016) emphasized the strategies of reuse, recycling, use of renewable energy sources and productivity targets towards circular economy. In June 2018, the country presented a white paper where it reaffirmed the country's commitment to stop all recycling imports by the end of 2020. Low carbon cities and industrial symbiosis have been set up in various regions of the country to facilitate achievement of the goal. *France* introduced a new CE law in February 2020 (Government of France, 2020). An year earlier, "National Pact on Plastic Packaging" had been launched with requirements for manufacturers and distributors of consumer goods to reach 60 percent of recyclable plastic by 2022 (Government of France, 2019).

The Framework Act on Resource Circulation (2016) of the *Republic of Korea* aims at CE creation. Larger enterprises are mandated to reduce waste to meet specified targets. The market of recycled products is facilitated through green public procurement and their on-line trading. To substitute and convert public recycling infrastructure, the government has been investing in supporting of installation and improvement of business recycling facilities, technology development and bringing it to the market, management training for recycling businesses. In *Japan*, the Fundamental Plan for Establishing a Sound Material-Cycle Society gives attention to life-cycle of plastic products and associated services, reduction in the use of plastics, particularly single-use packaging and products and microplastics (Government of Japan, 2018).

An ambitious programme towards circularity exists in the *EU*. The CE Package (European Commission, 2015), with reference to its communication "Towards a circular economy, a zero waste programme for Europe", proposes an aspirational 30 percent target on reduction of beach litter and fishing gear by 2020, with action plans for each of the four marine regions of the EU. The 7th Environment Action Programme (EEA, 2020) calls for the vision of a "CE where nothing is wasted and where natural resources are managed sustainably". The Programme also calls for the development of quantitative targets for reduction of marine litter.

5. Enabling instruments

The previous sections outlined elements for a comprehensive policy approach with life-cycle perspective and CE vision to prevent leakage of plastic into marine ecosystems. Their effectiveness though is contingent on enabling actions, as illustrated in Fig. 2. Circularity of plastics relies strongly on *innovations* in the area of technology, business and policy practices, and depends on targeted efforts in their development. Development of CE for plastics is a gradual process and its optimization depends on the knowledge of plastic pollution sources, pollution distribution and fate in the environment and calls for *systems of research and monitoring*. With 150 million tonnes circulating in the oceans today and 8 million tonnes of plastics added every year (Ocean Conservancy, 2020), the task of addressing *legacy waste* through retrieving leaked

plastic is critical to minimize serious damage to the marine ecosystems. Attention to *protection of marine ecosystems* lends yet another instrument for combating actions harming their health, and the health and well-being of communities that depend on them.

5.1. Knowledge development and monitoring

To address complexity of MPP, governments require knowledge of the problem, including sources of pollution, distribution patterns and data on the effectiveness of policy interventions. The governments have supported research and monitoring projects that aim at understanding the amounts, types and distribution patterns of MPP on the coast and nearshore environment as well as seabed litter in ports and major fisheries areas (e.g., *Australia, Republic of Korea, China* (Our Ocean, 2017), *India* (Karanir, 2018). They also focused on identification of key polluting activities (*France)* (UNEP, 2015)) or main polluters. Source assessment and monitoring result in modeling of distribution patterns (*Australia*), databases (*India*) and are often linked to other programmes, such as the development of a Total Management System for Marine Debris and restoration of coastal ecosystems in the *Republic of Korea* (Kang, 2019), the reduction programmes of the *EU Member States* under the Marine Strategy Framework Directive (Our Ocean, 2017).

Engagement of knowledge institutions is a common practice. *Australia*, for example, undertook a comprehensive study into source and fate of MPP, jointly through University of Western Australia, Commonwealth Scientific and Industrial Research Organisation, Australia's Marine National Facility, Australian Fisheries, Australian Institute of Marine Science, CSIRO's Flagship postgraduate scholarship, and the Shell social investment program (Shaw et al., 2013). Similarly, initiatives led by WWF and Vancouver Aquarium, and the Ocean Conservancy help to quantify and classify marine debris, including plastic waste in *Canada*. From 2017 Fisheries and Oceans Canada provides resources to the Vancouver Aquarium to implement Pollution Tracker and investigate pollution impact in the Pacific and Arctic Oceans. The aquarium also conducts a study on microplastics impact on marine life in the Arctic Ocean (Our Ocean, 2017).

Data collection and monitoring are used for specifying methodologies for research on marine plastic wastes – work critical for a deeper understanding of facts and the compatibility of data, especially in view of collaborative commitments of G20 member states. Within the Intergovernmental Joint Programming Initiative Oceans, *Germany*, *Italy*, together with nine other EU countries, have an ongoing commitment of over 7.5 million EUR on transnational research projects with a focus on microplastics in the marine environment. This aims at harmonization of methodologies and protocols for microplastics research (Our Ocean, 2017). Japan is also working on harmonization of microplastics monitoring in oceans since 2016 to arrive at a national procedure of Marine Microplastic Monitoring (MoEJ, 2018). The microplastic monitoring technology is also in focus of *China* (Qin, 2018).

5.2. Supporting innovations

Bioplastics stands out as a major focus for innovations to address plastic pollution, as countries extensively fund R&D for plastics innovation. Innovations and research are ongoing to find appropriate bio-based materials and biodegradation properties (Folino et al., 2020). The government of the *UK* plans to fund plastics innovation through a bid into the government's £7 billion research and development pot (PM Office, 2018). It will invest £60m in projects for development of bioplastics made from industrial or post-consumer food waste and increase the use of recycled content in plastic packaging (Barret, 2018). *China* has set up a special biomass equity fund intended, among other things, to support plastic-related research. The *US* has announced a contribution of USD 500,000 to the New Plastics Economy Initiative's Circular Design Challenge to identify solutions for new packaging and alternative business models for plastics (Our Ocean, 2017).

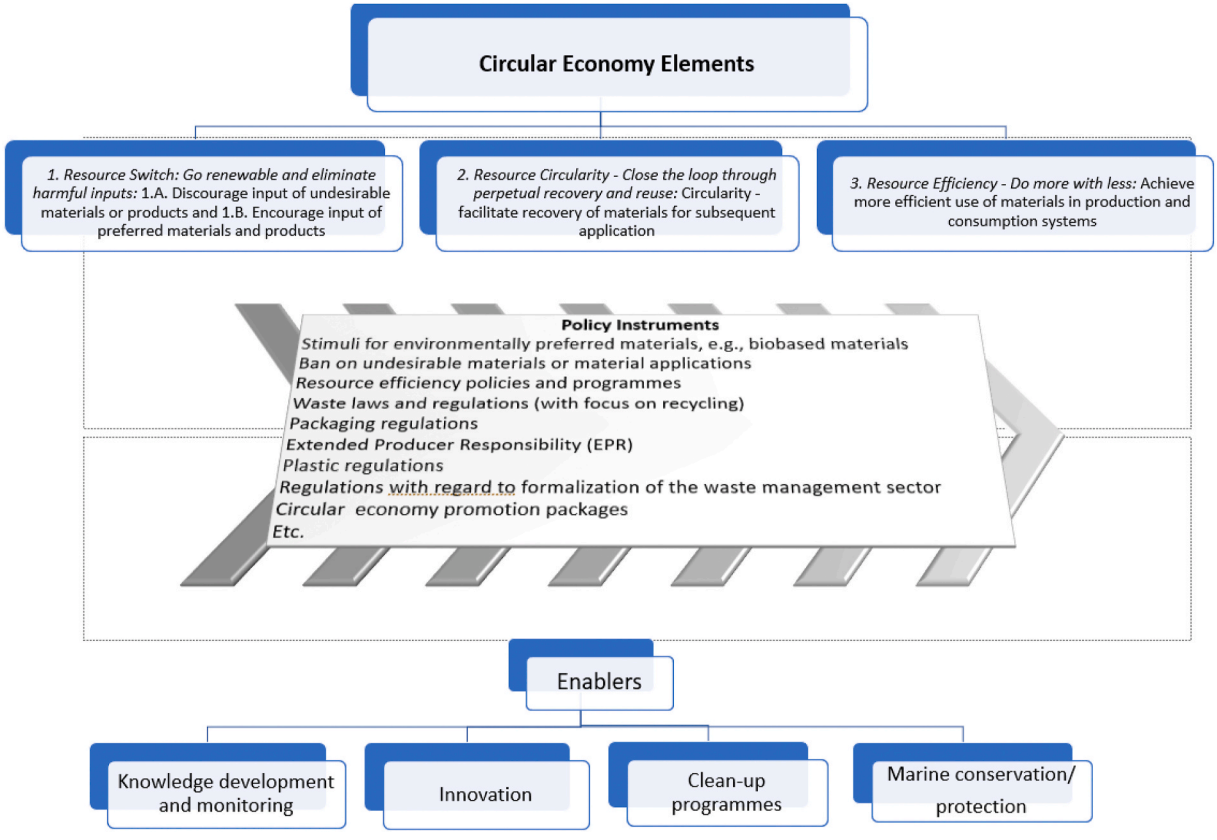

Fig. 2. Framework for appraising policy alignment for elimination of marine plastic pollution.

Some countries have been successful in promoting innovators to startups that have commercialized their innovative solutions, including towards MPP challenge. Programmes, often in strong partnership with academia or international organizations, have helped entrepreneurs to embody their ideas into products (or services), bring them to the market and to create business. (UNIDO&GEF, 2018).

5.3. Legacy marine plastic waste clean-up programmes

Removal of plastic debris already present in – marine – environment happens across G20 countries through clean-up campaigns and associated initiatives. Preventive action is though justifiable given high cost and limited recovery through clean-up operations. *US* spends USD 10.8 billion on litter clean-up with amount for cleaning marine litter in West Coast communities exceeding USD520 million (includes beach and waterways cleanup, street sweeping, storm water capture devices, storm drain cleaning and maintenance, manual cleanup, and public education). An amendment of the National Oceanic and Atmospheric Administration's Marine Debris Act was signed with funding allocated until 2022. The goal of the law is cleaning ocean plastic waste and improving waste management in order to prevent its leakage into the oceans (US Congress, 2018).

Many clean-up actions become formally linked with other policies dealing with leakage of plastics into the natural environment and based on partnerships. *Turkey* announced to develop Marine Litter Action Plans for all coastal cities. The plan will include clean-up activities, collaboration for marine litter minimization, pollution reduction studies and progress reporting (Our Ocean, 2017). Litter strategy for *England* (2017) introduced a system of measures ranging from education to infrastructure development and assessment of different reward and return schemes.

Innovative initiatives are also based on creating stimuli for collecting plastic waste from the ocean. All of *Germany*'s costal states (Umwelt Bundesamt, 2015) and many regions in the *UK* implement the Fishing-For-Litter Initiative where fishing vessels collect plastic with their nets and dispose of it in the harbors. Technology for removing marine plastic litter is also in the focus of attention, with *Germany*'s €50 million investment in the export of technology that removes marine garbage setting an example.

5.4. Marine conservation and protection programmes

Several Regional Seas Programmes (UNEP, 2020), the Regional Seas Conventions and Action Plans and national laws and programmes focus on planning, licensing, conservation and enforcement of marine protection. While these do not necessary directly address MPP, by introducing regimes of more stringent control over water and land activities, including fishing, they present an additional effort towards MPP elimination.

UK is one of the countries that have dedicated Marine Acts[5] - the laws that mandate allocation of resources, institutional arrangements and allocated responsibilities for protection of marine life. Legal framework also exists in *Indonesia* where the Maritime Law, too, contributes to MPP reduction (Government of the Republic of Indonesia, 2014).

Designation of protected marine areas is important, *Argentina* has established two new marine protected areas – Yaganes and the extension of Namuncurá-Burdwood Bank contributing close to 100,000 square kilometers to costal marine protection. *Mexico* has announced the establishment of Revillagigedo National Park of 140,000 square kilometers, protecting the islands and surrounding waters, with a total ban of fishing activities in the area (Our Ocean, 2017).

Management of marine environment comes with announcements of financial commitments. *Republic of Korea* committed to invest, annually, EUR 28 million to manage the marine environment around the Korean Peninsula. This investment also foresees monitoring of the inflow of pollutants into the sea, restoration of coastal ecosystems and research on marine litter (Our Ocean, 2017).

6. Final observations

MPP has come in focus as oceans of the world are being turned into plastic soups as a result of continued widespread littering and leaking waste management systems – this is a thorn in the eye for tourism and coastal zone development, interferes with fishing and impacts wildlife. Several consecutive and parallel international, regional and national processes and initiatives have put CE firmly on the agenda to minimize MPP at source, given the inability to recover plastic litter from seas and shores. CE is attractive to embrace conceptually, however, this conceptual acceptance, hides that CE means many different things to different producers, consumers and governments. Hence, we first clarified operational scope of CE, through switch, efficiency and circularity of resources, and illustrated each with plastic related actions.

A worldwide, actionable framework is urgently needed. The global scale of MPP, the dominance of indirect and highly diversified land-based sources (relative to seashore and sea-based sources) and resultant diversity of technological, management and behavioral solutions, all stand in the way of joint understanding and collective policy initiative and actions of producers, consumers and waste managers. Hence, we coupled the comprehensive CE operationalization with a life-cycle perspective of plastics production, use and recovery to map the policy space for MPP prevention.

Putting the inventory of G20 initiatives on this MPP 'policy map', revealed that G20 members have undertaken a variety of MPP-related actions that contribute differently to CE. Despite significant variations between countries, there is common trust around, firstly, discouraging plastic materials for application in short-lived products and packaging ('*single use plastics*'), secondly, encouraging bio-based and biodegradable plastic substitutes, and thirdly, improving plastic waste collection and recycling. This is being supported and informed by knowledge and capacity building initiatives. From a CE perspective, the primary focus is on resource circularity, with notably less focus on resource switch and, even less, resource efficiency. This reveals on one hand the difficulty for policy makers, often working within strict sectoral mandates, to design and roll out a systems approach to MPP, and on the other hand a reflection of the need to balance the societal benefits (health, food safety, energy, environment, etc.) of plastics use against the negative environmental impacts of plastics, including MPP. Complexities that are further aggravated by the truly international and global dimension of the fight against MPP, as also observed with other global environmental challenges, such as climate change, biodiversity and protection of the ozone layer.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[5] The UK Marine and Coastal Access Act (2009), Marine (Scotland) Act (2010) and Marine Act (Northern Ireland) 2013.

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