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Enhanced plastic economy: a perspective and a call for international action

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The worrying plastic pollution has led to global attention to control it and the emergence of a circular plastic economy. However, the current circular plastic economy seems to lean towards recycling of and energy recovery from plastics, and its implementation is widely varied. To ensure the effectiveness and uniformity of the plastic economy and learning from the successes and failures of the carbon economy, this article provides a perspective on an enhanced plastic economy to serve as or contribute to an international framework in mitigating plastic pollution. It deems that a separate international treaty or a treaty under the carbon economy to specifically address plastic pollution is beneficial as it promotes policy and legislative reforms in participating countries while providing more centralized policy support and instruments to operationalize regional plastic economy. More ambitious target-setting for the reduction of conventional plastic production and consumption, devoid of the excessive flexibility of the carbon economy encourages the development of a new market for green plastic substitutes and reduces carbon emissions from the lifecycle of conventional plastics. Economic instruments including taxes and incentivization of plastic substitutes, with or without plastic cap-and-trade are beneficial to the operationalization of an enhanced plastic economy, which could also contribute to reducing fossil fuel consumption and mitigating climate change. An international agreement to reduce mismanaged plastics through target-setting is another approach to control plastic pollution. The achievements of targets by participating countries can then be tracked through an established monitoring and reporting system, followed by adjustment of targets for improved effectiveness. The agreement could also address the transboundary movement of plastic waste to prohibit secretive diversion of the waste to developing countries.

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Environmental significance

In view of a lack of synchronous effort to address the global plastic problem, and hence the absence of a centralized support for curbing global plastic pollution and monitoring of its progress, this paper provides a perspective on a preliminary unifying framework of an enhanced plastic economy, incorporating lessons learnt from the carbon economy. It has the significance of filling in the shortcomings of the current circular plastic economy which overly focuses on recycling and reuse. It advocates for a systemic top-down approach to drive the enhanced plastic economy and curb plastic pollution through international treaties. It contributes ideas to more effective operationalization of an enhanced plastic economy and strengthens the call for international commitment to reduce plastic pollution.

1. Introduction

Ever since microplastics have been detected in food, drinking water and air, plastic pollution has come to the attention of people around the world.[1] There has been increasing research launched into various facets of plastics, including microplastics, which encompasses their abundance, distribution, fate and transport in different environmental media, as well as their ecotoxicity.[2–4] Microplastics are now present in many remote regions of the world. Microplastics were found in Arctic snow samples at concentrations up to 14.4×10^3 items per liter.[5] The ice core of the Arctic Fram Strait contained a maximum concentration of 1.2×10^7 microplastics per m^3.[6] Microplastics were also reported in the remote ecosystems of Antarctica with 0.01–3.29 items per mg of microbenthic samples retrieved from the Ross Sea.[7] Microplastics could potentially induce deleterious immune and stress responses, as well as interfere with reproductive functions and growth of animals.[8] Microplastics were revealed to adsorb other environmental pollutants, release plastic additives and provide surfaces for microbial growth, resulting in their altered or enhanced ecotoxicities.[9–11] As evidence is pointing to the severity of the problem with microplastics now permeating every corner of the environment, alleviating plastic pollution has become increasingly important. Multiple measures have been proposed, with each claiming to

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solve the plastic problem, but the plastic production rate is still on the uptrend and the amount of mismanaged plastics mirrors plastic production. Plastic production was 270 million tonnes in 2010 but as of 2021, it stood at 390.7 million tonnes.[12] In 2016, 91 million tonnes of mismanaged plastics were generated and the weight is projected to rise to 239 million tonnes by 2040.[13]

The statistics of plastic production and mismanaged plastics do not seem to align with the greater emphasis to control plastic pollution, and it leaves doubts about whether measures such as imparting awareness to reduce plastics use and the circular plastic economy are effective. Studies have pointed to increasing awareness among the public of plastic pollution and the adverse impacts of plastics, but awareness might not necessarily translate into actions for reducing plastic consumption, predominantly due to the wide presence of plastics in various consumer products, habits, the unavailability of alternatives and inconvenience.[14,15] This implies that a systemic top-down approach might be crucial, in addition to education and imparting awareness.[16] The circular plastic economy has been lauded as an important milestone in solving the plaguing plastic problem. It involves careful consideration of each stage of the plastic lifecycle from design, production, and consumption to end-of-life management.[17] As it unfolds, there seems to be much focus on the recycling of and energy recovery from plastic waste in comparison to other stages, particularly the design of plastic products to increase recycled and recyclable contents.[18] The differential emphasis on different elements of the circular plastic economy has led to nuanced ideas of its operationalization. The Ellen Macarthur Foundation, whose early definition of the circular economy has been widely used or popularized in multiple literature studies,[19,20] states that operationalization of the plastic circular economy takes three measures, namely (1) elimination of contaminating and excessive plastic materials, (2) innovation to create reusable, recyclable or compostable plastics, and (3) circulation of plastics through reuse, recycling and recovery. In this context, the circular plastic economy goes beyond reusing, recycling and recovering, to progressive innovation of plastics.[21] The operationalization of the circular plastic economy has been further refined but it does not depart from the central tenet. Kirchherr *et al.* integrated the concept of sustainability with the circular economy where the authors promulgated that the circular economy should offer environmental, economic and social benefits as it reduces material and energy inputs, sources renewable feedstock and energy, reduces wastage and costs, recycles resources, and generates new opportunities and cooperations.[20] In the same vein, a latest review of the definition of a circular economy by Kirchherr *et al.* found reuse and recycling to still occupy a central position with the emerging concepts of sustainable development, value maintenance and systemic shift trickling as in ref. 20. A major and systemic shift implies the need for a new paradigm in supply chains. In parallel to this, a shift in the current plastic economy to a circular one is crucial and it would be helpful to make a distinction between conventional petroleum-based plastics and innovated plastics made of 'green' materials to facilitate subsequent discussions.[21]

Currently, the lack of a framework for the circular plastic economy has resulted in it being operationalized differently in different nations. The European Union (EU) seems to lead the move currently through the adoption of the (EU) plastics strategy on 16 January 2018. The strategy aims to turn plastic recycling into a profitable business, reduce plastic waste, innovate plastics and drive changes globally.[22] The strategy resulted in the enforcement of the directive on single-use plastics on 2 July 2019 and a new circular economy action plan on 11 March 2020. It culminated in the communication on a policy framework for biobased, biodegradable and compostable plastics on 30 November 2022 which gradually steps up the reuse and recycling of conventional plastics as well as the use of innovated plastics.[22] In Canada, the Single-use Plastics Prohibition Regulations came into effect on 22 June 2022, putting a ban on the production, import and sale of single-use plastic items consisting of checkout bags, cutlery, food packaging, ring carriers, stir sticks and straws.[23] The regulations, however, do not seem to expand the plastic circular economy beyond the reduction of conventional plastics use. The United States responded to the global call to reduce plastic pollution through the National Recycling Strategy published in November 2021 to scale up plastic recycling. While there are separate programs addressing the elements of a circular plastic economy, there is a lack of integrated measures and legislative endeavors.[24] Australia passed the Plastic Reduction Act on 8 April 2021 which, like the Plastics Prohibition Regulations, serves to control the supply of single-use plastic items. Australia has also rolled out the National Plastics Plan 2021 aiming to phase out problematic plastics and scale up recycling.[25]

In developing countries, the House Bill 9147 was drafted in the Philippines to ban the production, import and sale of an array of single-use plastic items.[26] Public uproar on the debilitating impacts of plastic pollution in Thailand led to the roll-out of the Roadmap on Plastic Waste Management aiming to control the use of thin plastic bags, polystyrene food packaging, single-use plastic cups and plastic straws.[27] The implementation of regulatory control on plastics in the Philippines and Thailand is often faced with the challenges of inadequate legislation and enforcement as well as institutional fragmentation and a lack of power delineation.[27] In addition, much focus is placed on banning, hence reducing the consumption of single-use plastic items rather than establishing a full circular plastic economy. It is apparent that the operationalization of the plastic circular economy varies in different countries as a framework is missing, leaving countries to implement it based on how it is defined. To garner concerted effort in tackling global plastic pollution, the United Nations (UN) has initiated a discussion on the framing of an international treaty addressing plastic pollution by 2024 through the Intergovernmental Negotiating Committee (INC) but the negotiation is still at an early stage and there is no consensus yet on the mechanisms to control plastic pollution.[28]

2. Lessons from the circular carbon economy

The carbon economy has been established to reduce carbon emissions in the fight against climate change. It is closely

related to international efforts to reduce carbon emissions.[29] It is driven by multilateral treaties, particularly the United Nations Framework Convention on Climate Change (UNFCCC) which initially aimed to stabilize the concentrations of atmospheric greenhouse gases within a reasonable timeframe.[30] The UNFCCC resulted in extensions such as the Kyoto Protocol which spells out the differentiated responsibilities of the parties to reduce greenhouse gas emissions through flexible market-based mechanisms comprising international emission trading, clean development mechanisms and joint implementation.[31] The ensuing Paris Agreement enforced on 4 November 2016, further commits its parties to reduce greenhouse gas emissions through progressive goal setting while establishing a monitoring and reporting mechanism for the achievement of national climate goals.[32]

These treaties pave the way for a carbon economy. Initially, the carbon economy was called a low carbon economy characterized by facets consisting of low energy consumption, low carbon emissions throughout product and technology lifecycles, as well as the development of technology to capture and recycle carbon dioxide.[33] The low carbon economy serves to establish mechanisms to reduce carbon emissions in meeting or exceeding the targets of the Kyoto Protocol.[33] Subsequently, variants of the low carbon economy emerged but the concept remains largely unchanged. A variant called the circular carbon economy is formed from the merging of the carbon economy and the circular economy. The circular carbon economy features the reduction of carbon emissions, the reuse of carbon for feedstock and fuels, the recycling of carbon for bioenergy in addition to the removal and storage of excessive carbon. It is analogous to the low carbon economy with an additional emphasis on the reuse and recycling aspects.[34] Another variant is the all-encompassing green economy to capture the diverse elements of the carbon economy, especially low carbon and efficient use of resources, besides addressing social equity.[35] Public and private investments are crucial in the green economy to spur infrastructural development and economic activities towards sustainability. This is translated into carbon emission reduction, pollution alleviation, environmental and biodiversity conservation, better employment opportunities and higher income.[36] The success of the green economy depends to a large extent on policy and legislative reforms. The green economy serves to complement sustainable development through policy mainstreaming at national and regional levels, development of economic instruments and capacity building.[35] It integrates resource efficiency in addition to sustainable consumption and production, and requires partnership between governments, businesses and citizens to play out.[36]

The Paris Agreement has endeavored to cap global warming below 1.5 °C above pre-industrial temperatures but the limit is likely to be exceeded by the 2030s, casting doubt on the effectiveness of the Paris Agreement and the carbon economy.[37] The Paris Agreement has been perceived as not sufficiently ambitious to reduce global warming and the earlier Kyoto Protocol conferred flexibilities to developing countries including the largest carbon emitters in taking actions to reduce carbon emissions.[37] In relation to the carbon economy, intensive subsidization of renewable energy in Germany did not seem to substantially reduce carbon emissions due to the weak carbon price. In contrast, taxing the emissions from the energy sector in the UK has successfully reduced carbon emissions.[38] It is argued that the replacement of coal plants with gas plants could downplay the importance of carbon pricing[38] while Boyce opined that carbon pricing assumes a crucial role in spurring the mitigation of climate change.[39] While the views on the effectiveness of international treaties and the carbon economy in combating climate change vary, the carbon or green economy has provided examples of instruments that could benefit or enhance the current plastic economy. The instruments include legally binding international treaties, target setting, trading systems, and taxation. Carbon pricing is tricky in the face of an extremely wicked problem like climate change. The aim of carbon pricing is such that the costs of negative externalities associated with carbon emissions could be funneled to carbon emitters. However, it is argued that climate change is a system problem with crucial societal functions like heating and transportation which is not easily resolved by addressing market prices.[40] Besides, carbon pricing could promote the seeking of the most straightforward rather than the most effective carbon-mitigating strategies, thus downplaying the importance of a systemic transformation.[41] In contrast, carbon pricing also drives innovation in carbon mitigation.[39]

Plastic pollution is also a wicked problem in the sense that conventional plastics are tied to many aspects of everyday life since they are found in an extremely wide range of items. Despite efforts to reduce plastic use, the production of plastics is still on the rise. There is a need for transformation in the lifecycle of plastics and, like climate change, it requires a systemic approach. Besides, economic instruments need to be used with care to drive innovation in the plastics value chain and push for more environmentally friendly plastic substitutes. While it remains uncertain whether the plastic economy will employ a trading system similar to that of carbon, economic instruments generally could provide an avenue to address the costs associated with the negative externalities of plastics.

3. Enhanced plastic economy

It is undeniable that the carbon economy has its drawbacks and requires intensification to ensure that climate goals could be met within the set timeframe. Nonetheless, it has changed the global energy landscape, leading to or catalyzing the emergence of cleaner energy, low-carbon technology and carbon emission reduction.[42] The instruments employed in the carbon economy may offer opportunities for the enhancement of the circular plastic economy. Success in the circular plastic economy also contributes to the reduction of carbon emissions since the production of conventional plastics are dependent on fossil fuels. An estimation revealed that conventional plastics emitted 1.7 gigatons of carbon dioxide equivalent over their lifecycles in 2015 and the emission was projected to increase to 6.5 gigatons under business as usual by 2050, equivalent to 15% of the global carbon budget.[43] In this sense, a circular plastic economy is

linked to the carbon economy and could contribute to resource efficiency of the green economy.

As with the carbon economy, the plastic economy requires international commitment *via* legally binding international treaties akin to the Kyoto Protocol and Paris Agreement, without which regional and national policy and legislative reforms would be difficult and asynchronous, leading to differential implementation which could be compromised by socio-political situations.[27,44] Learning from the shortcomings of the Kyoto Protocol and Paris Agreement, the international treaties for the plastic economy could push for more ambitious goals progressively and garner more active participation of the developing countries which are also major plastic producers and consumers. There has been sporadic imposition of legal plastic bans with the EU leading the move.[23,25] The EU's circular economy action plan could offer a model for such reforms.[18] Prior to this, countries need to be brought to a common ground through international agreements to contribute to the alleviation of plastic pollution. Such agreements can garner the commitment of participating countries in numerous ways to reduce plastic pollution, namely through (1) capping the production of conventional plastics in a manner similar to limiting carbon emissions through target-setting; (2) developing market-based instruments that facilitate the attainment of the production target; (3) enabling progressively ambitious target-setting; (4) catalyzing the development of environmentally friendly plastic alternatives similar to the development of renewable energy in the quest to reduce carbon emissions (Fig. 1).

Besides, international agreements on plastic waste management are beneficial to address issues related to transboundary movement of plastic waste and mismanagement of plastic waste.[45] For instance, such agreements may also function to control the generation of mismanaged plastic waste by participating countries *via* progressive target setting. These international agreements siphon the commitment necessary for mainstream policymaking at national and regional levels while providing policy support to permit the establishment of the circular plastic economy and strategies (Fig. 1). Regulations on the transboundary movement of waste should also address issues related to the disposal of plastic waste by developed countries to developing countries. This requires transparency in monitoring and reporting the amount of plastic waste generated locally and the disposal fates of the waste, including its ultimate fate if traded across borders.[46] Much of the plastic waste generated by the developed countries was shipped to China prior to its ban on plastic waste import, which has apparently created repercussions on plastic waste disposal strategies of the developed countries and raised questions of their effectiveness.[47] The plastic waste was subsequently diverted to other developing countries whose capabilities to handle the waste remain questionable.[47] Screening, limiting and tracking the plastic waste traded across borders are therefore crucial facets in regulating transboundary plastic waste.

An economic instrument akin to the cap-and-trade system of the carbon economy could be employed for the plastic economy, rendering the plastic production credits tradable (Fig. 1). Like carbon credit trading, plastic credit trading is foreseen to promote technological innovation for the reuse and recycling of conventional plastics as well as the development of green alternatives for conventional plastics. However, the pricing of plastic credits should be carefully approached if plastic credit trading was to be adopted. The pricing should be at a level that is effective in limiting the generation of conventional plastics.[48] Otherwise, it is destined to follow the path of the non-prohibitive carbon pricing. International effort to reduce mismanaged and transboundary plastics is complementary to the plastic economy as both merge in the reduction and proper end-of-life management of conventional plastics to make sure they do not leak into the environment. Better plastic waste management can be perceived as a co-benefit of the plastic economy (Fig. 1).

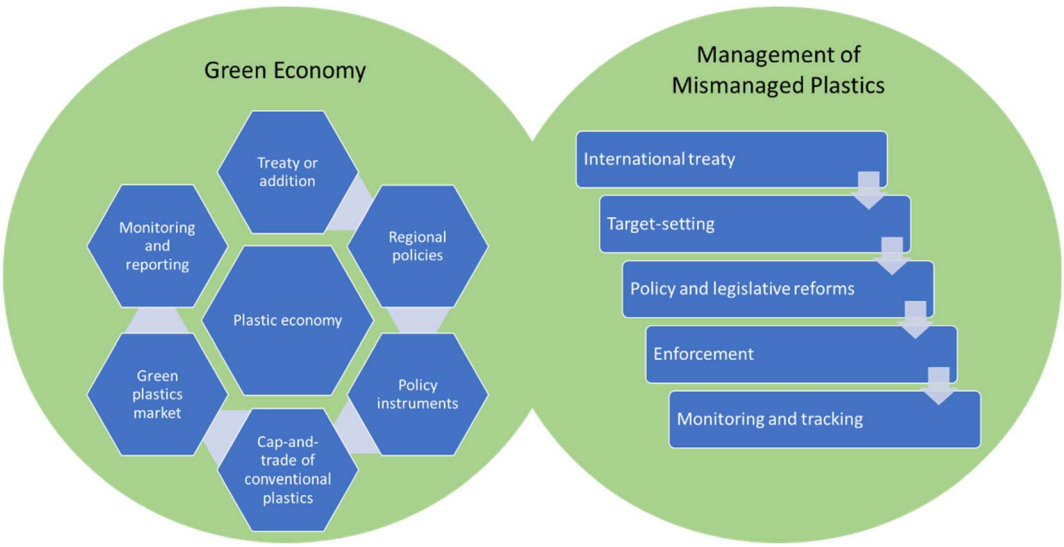

Fig. 1 A framework of the enhanced plastic economy.

Centrally directed policymaking and policy support is likely to drive new business models focusing on the careful design of plastic items to permit their end-of-life reuse and recycling, in addition to conventional plastic recycling businesses to turn recycled plastics into feedstock for the production of new plastic items. The business models encompass the lifecycle management of green plastic substitutes, for instance the recovery of energy and nutrients from green plastic materials through anaerobic digestion and composting. The EU has pioneered this type of policy and business model through the inception of a policy framework on biobased, biodegradable and compostable plastics to reduce its dependence on conventional plastics and create new business opportunities in this dimension.[22] Biobased plastics are biomass-based plastics and they are not always biodegradable. Biodegradable plastics are biomass-based or fossil fuel-based plastics which are biodegradable. If biodegradable plastics could be degraded through composting, they are called compostable plastics.[49] While these plastics are not totally devoid of environmental impacts, they offer a channel to reduce the reliance on fossil fuels as major raw materials for plastics, and hence, the associated climate implications.[50]

New plastic business models should ideally address economic and social sustainability by means of encouraging the emergence of new profitable businesses, generating new jobs, and contributing to capacity building, research and innovation. Currently, the plastic economy is linked to the carbon economy through carbon emission reduction targets and plastics taxes.[51] As for the former, since plastics are not the major contributors of greenhouse gases in comparison to the energy and transportation sectors, reducing carbon emissions through reducing plastics in the carbon economy is not deemed to be feasible, especially with more stringent climate goals introduced. The current plastics taxes aiming to combat climate change, such as those in Spain and the United Kingdom, elicit a clearer link between carbon and plastic economies, but the taxes often lack comprehensiveness.[51] A comprehensive tax system for plastics could be instituted for the plastic economy to deter the production and consumption of conventional plastics. Having said that, the plastic economy could complement the carbon economy by aiming to reduce fossil fuel production for plastics manufacturing, an apparent mitigating move that the carbon economy has failed to push for.[52] This requires international consensus to impose a progressively tightened fossil fuel quota for plastics manufacturing and not channel the fossil fuels saved to other industries.

The enhanced plastic economy has the potential to provide a clearer framework for the current plastic economy and improve its operationalization. It could also serve as a reference to the Global Plastics Treaty which is currently in the process of negotiation. The negotiation aims to culminate in international commitment to control plastic pollution through legally binding instruments by 2024.[28] However, the INC has yet to determine the mechanisms to address the global plastic problem, though preliminary ideas such as the circular economy to drive sustainable production and consumption of plastics have been mentioned.[53] The enhanced plastic economy discussed herein could complement the preliminary ideas of the INC by promulgating a top-down systemic shift away from the conventional plastics *via* progressive capping of production and consumption of conventional plastics coupled with a simultaneous development of a green plastics market to make plastic substitutes available and propel new businesses of plastic substitutes. In doing so, taxes on plastic production and consumption, and incentivization of businesses related to environmentally friendly plastic substitutes are crucial. The INC might consider aspects of the enhanced plastic economy related to the reduction of mismanaged plastics *via* designs that reduce plastic components, promote the use of recycled plastics as well as facilitate the recycling of plastic components. Besides, the INC could address the transboundary dimension of the mismanaged plastics by setting progressively more stringent targets on mismanaged plastic reduction and the tracking of plastic waste bound for transboundary disposal. To ensure its effectiveness, monitoring, reporting and continuous improvement are crucial. Countries committed to this economy and the Global Plastics Treaty would be engaged in tracking and reporting their achievements as well as continual target setting to propel the continuous improvement of the plastic economy. It is possible to integrate the plastic economy into the existing carbon or green economy but it needs to stand out from other major contributors of greenhouse gases the carbon economy aims to address, since conventional plastics are not only contributing to greenhouse gases, but are also a major source of global pollution.

4. Conclusion

In its present form, the plastic circular economy places a skewed emphasis on the recycling and recovery of energy from plastic items. Its operationalization often hinges on its definition to address the plastic life cycle in facilitating their end-of-life management. There is a lack of a unified framework to put the plastic circular economy into practice, resulting in widely varied implementations with certain regions having more comprehensive strategies than others, and certain countries being devoid of plastics policies or regulations. For countries instituting plastics laws, the laws are frequently confined to prohibition of selected plastic items. Plastic production and consumption contribute to carbon emissions. Though the effectiveness of the carbon economy has been subjected to heated debates, some measures employed could be applicable to the enhanced plastic economy, and they are typified by international treaties to garner commitment, more synchronized policymaking and employment of policy supports, progressive capping of conventional plastic production as well as the development of market-based instruments to promote the reduction of conventional plastics and drive the growth of the green plastics industry. These measures and the lessons from the carbon economy could contribute to shaping the framework of the enhanced plastic economy and the Global Plastics Treaty currently in negotiation. While it remains uncertain if the enhanced plastic economy would take on the path of cap-and-trade, economic instruments such as taxes and

incentivizing plastic substitutes are instrumental. Securing commitment through treaties ensure that participating countries are engaged in achieving their respective targets to reduce plastic pollution while enabling a common monitoring and reporting strategy to track the progress and effectiveness of the national or regional policies and programs. The plastic economy could be established as a subset of the carbon economy but there should be a strong focus on the curbing of plastic pollution in view of its severity or perceived severity. Having said that, an axis to pull the effort to ameliorate plastic pollution is instrumental to engender the commitment needed and this article, therefore, calls for the development or hastening of international actions, if plastic pollution is as serious as it is portrayed to be scientifically and politically.

Conflicts of interest

There are no conflicts to declare.

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