Global Plastic projections to 2050: economic drivers and environmental consequences

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ABSTRACT

Plastics are one of the most commonplace materials on the planet. In 2015, global plastics production reached 407 million tonnes per annum (Mtpa). If growth persists at similar rates, plastics production is expected to reach 1 600 Mtpa in 2050. The extraction of materials required for plastics production, as well as the use and disposal of plastic products is creating significant environmental pressure, with serious consequences for ecosystem, health,…. The most apparent environmental impact is the ubiquitous plastic pollution and especially plastic litter in the ocean.

While projections of plastic use already exist in the published literature, they are generally linked to projection of specific sectors, or are the results of engineering models that describe in details the lifecycle of plastic commodities but do not include these details into a global macroeconomic framework. This paper present more to make some realistic projections to 2050 about plastic production, use and waste as they are based on a dynamic CGE model (the ENV-Linkages model). Because the strength of CGE is to detail the drivers of structural change, such as changes in demand patterns, production modes (including increases in recycling activities) and trade specialization, these factors will explain why future demands for plastic do not exactly follow economic growth and population, as naïve projections do.

This paper is built on modelling methodology developed for material projections of the recent OECD Global Material Resources Outlook (2019). In this perspective, this paper take advantage of the new GTAP10 database split of the old "crp" sectors into 3 new sectors, including plastic. The final objective of the paper is to improve knowledge and projections of the economic drivers of the production and use of plastic to support better policy making that aims at sustaining economic growth while improving environmental quality. This will be achieved by gathering existing information on plastic to finally enhance projections about the economic drivers of refined materials (in particular plastic) throughout the whole economic value chains.

The paper would also propose projections of plastics waste under different baseline scenarios, including updated SSP growth scenarios.

Contents

1. Introduction

1.1. Context and previous work on plastics

Plastics are one of the most commonplace materials on the planet. In 2015, global plastics production reached 407 million tonnes per annum (Mtpa), making it more than the production of paper (400 Mtpa)[1] and aluminium (57 Mtpa).[2] If growth persists at similar rates, plastics production is expected to reach 1 600 Mtpa in 2050.[3,4]

The extraction of materials required for plastics production, including oil extraction and refining, as well as the use and disposal of plastic products is creating significant environmental pressure, with serious consequences for ecosystem health and human well-being. The most apparent environmental impact is the ubiquitous plastic pollution. Plastic litter is present in all the world's ocean basins, including around remote islands, the poles and in the deep seas, and an additional 5 to 13 million tonnes are estimated to be introduced every year to the oceans.[5] This material will only decompose over the course of hundreds, if not thousands, of years.

Past and ongoing OECD analytical work on plastics has focused on two topics: on the crosscutting issue of the sustainable design of plastics and on secondary plastics markets. Ongoing work in the current biennium expands analysis to plastics waste streams that are of particular concern for oceans, such as microplastics and single-use plastics.

While some of the above-mentioned work is expected to continue, it is proposed to complement these focussed reports with the development of an integrated Global Plastics Outlook to 2060. This work would build upon past OECD Environmental Outlooks (2001, 2008, 2012), the Environmental Outlook for the Chemicals Industry (OECD, 2001) and the recent Global Material Resources Outlook (OECD, 2019). It would mobilise and further extend the OECD environment-economy modelling capabilities to project the economic drivers of global plastic production and use, and connect these to indicators about plastic waste and plastic pollution.

1.2. The Global Plastic Outlook

The Outlook would include projections of plastic production and plastic waste, under different scenarios, about future global socio-economic trends, connecting them to their impact on marine plastic pollution. This work would allow to assess the environmental impacts of policy inaction about plastics waste management. As a first step, the goal is to understand the economic drivers of plastics across its full life cycle, and in particular how economic growth and economic trends (like structural changes) determine in fine amount of plastic use. In a second step, extensions of the

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[1] WWF (2018), Pulp and paper, http://wwf.panda.org/about_our_earth/deforestation/forest_sector_transformation/pulp_and_paper (accessed on 28 March 2018).

[2] USGS (2016), Aluminum Legislation and Government Programs, https://minerals.usgs.gov/minerals/pubs/commodity/aluminum/myb1-2015-alumi.pdf (accessed on 28 March 2018).

[3] The rapid growth of plastics use is largely due to its unique properties. Plastics have a high strength-to-weight ratio, can be easily shaped into a wide variety of forms, are impermeable to liquids and highly resistant to physical and chemical degradation. Plastics can also be produced at relatively low cost. These properties have led to the substitution of traditional materials (e.g. concrete, glass, metals, wood, natural fibres) by plastics in many applications.

[4] EMF (2017), Rethinking the future of plastics and catalysing action, https://www.ellenmacarthurfoundation.org/assets/downloads/publications/NPEC-Hybrid_English_22-11-17_Digital.pdf.

[5] Jambeck, J. et al. (2015), "Marine pollution. Plastic waste inputs from land into the ocean.", Science (New York, N.Y.), Vol. 347/6223, pp. 768-71, http://dx.doi.org/10.1126/science.1260352.

modelling work would include a quantification of the impact of market and non-market policies to combat plastic waste generation and its leakage into the ocean, as well as an assessment of the investment needs and costs to achieve these objectives.[6]

This work would provide an integrated and coherent framework for analysing the socio-economic drivers of plastics. It would also allow to analyse the role of multilateral and co-ordinated action in achieving environmental objectives, as plastics feedstocks, plastic polymers, and to a lesser extent, plastics waste are internationally traded commodities.

The modelling work would be complemented by in-depth analysis in a number of areas, that will be discussed in other parts of the Plastic Outlook, which could potentially include:

- A global stocktake of recent modeling efforts on plastics.
- An improved understanding of the drivers of the likely projected increase in the demand for refined materials (including plastics and textiles) in the coming decades, under the current policy framework.
- A stocktake and evaluation of progress of policy responses implemented in OECD and non-OECD countries along the value chain to reduce the environmental externalities associated with plastics.
- A review of key market trends and policies on primary and secondary plastics. Ongoing work on plastics recycling technologies could also inform the modelling exercise.
- An evaluation of the environmental and economic consequences of recent measures to address trade in plastic waste.
- An assessment of the state of green innovation in the plastics sector (e.g. related to sorting and recycling, bio-degradable and bio-sourced plastics, sustainable plastics design).

Such an Outlook would offer the opportunity to develop a first of its kind reference on plastics production, pollution and policy responses. It could also serve as input to the next OECD Environment Ministerial and offer a timely opportunity for Ministers to take stock of the impact of this recent wave of actions by governments, civil society and the private sector to combat plastic pollution.

The Outlook could seek to answer the following questions:

- What will be the likely increase in plastics production, use and pollution in the coming decades?
- How will alternative changes in economic structures affect these trends (e.g. transition to low carbon economies or potential short or long-term change in behaviours implied by COVID-crisis) ?
- Do plausible shifts away from plastics to alternative materials (biomass, glass, metals), where relevant (e.g. in the case of single use plastics), lead to significant improvements in terms of plastic use?
- What will be the likely increase in plastics waste generation in the coming decades in the absence of new policies?
- What are the environmental implications of an increase in plastics waste on the environment, and in particular on oceans?
- What is the economic and environmental effectiveness of selected policy responses in curbing plastics waste generation and related pollution?
- What are the investment needs to address plastics waste and reduce the environmental damages associated with plastics?

[6] This is in line with past OECD Environment Outlooks, which assessed the consequences of inaction, as well as the costs and benefits of action.

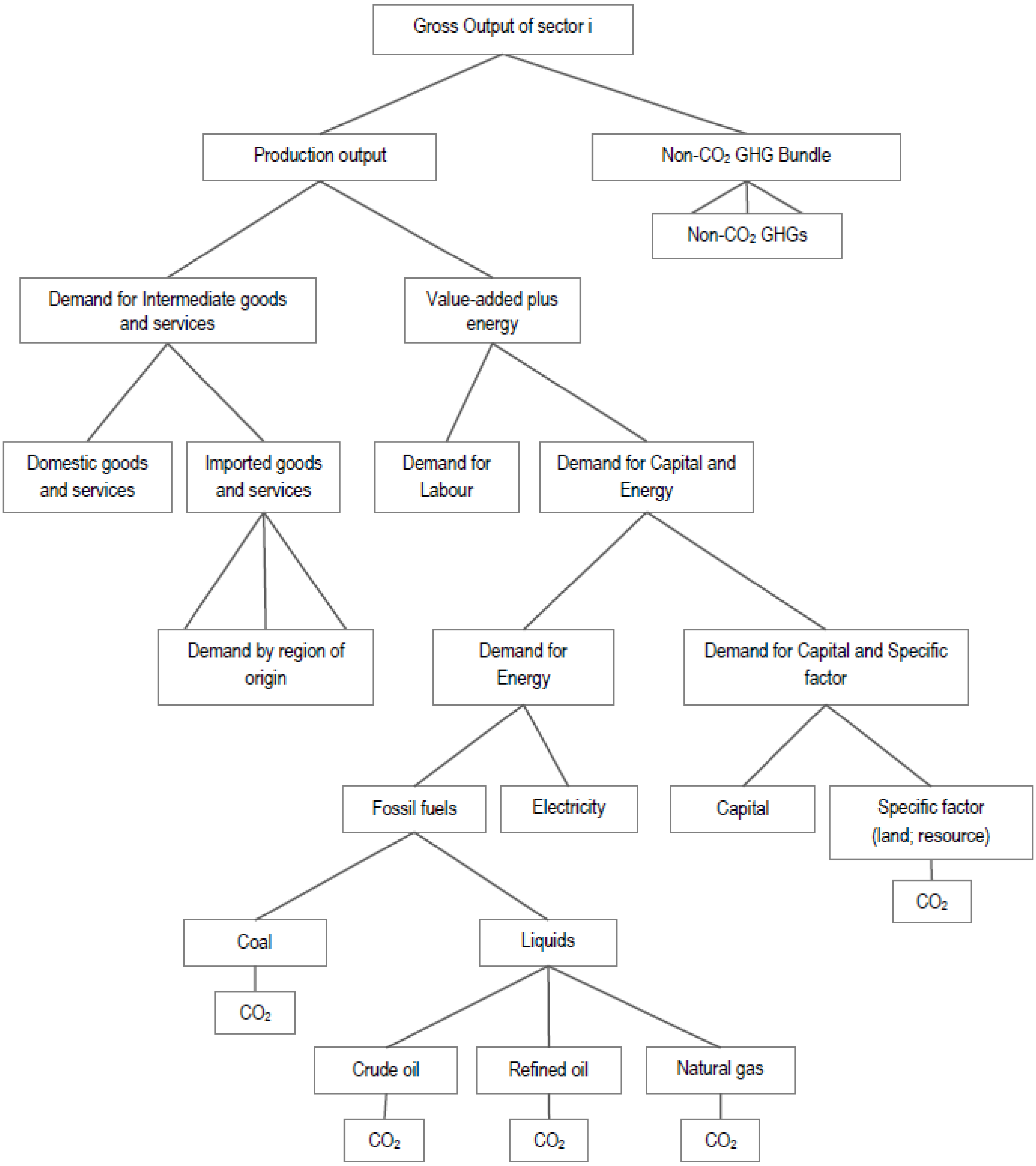
2. The modelling tool for this project

2.1. The broad structure of the ENV-Linkages model

The OECD in-house modelling tool, the ENV-Linkages model, is a computable general equilibrium (CGE) model based on the GTAP national accounting database (Chateau, Dellink and Lanzi, 2014). It describes economic activities in different sectors and regions and how they interact. It is also a global economic model featuring all the main regions or countries of the world. The model is built on a consistent set of data describing the behaviour of production sectors and consumers in the different regions, with a focus on energy and international trade. One of the main strengths of the model is to link economic activity to environmental pressures (e.g., greenhouse gas (GHG) emissions and Air pollutants) and to shed light on the medium- and long-term impact of environmental policies.

ENV-Linkages is a calibrated dynamic CGE model, which allows for better exploiting the sectoral details in assessing the environmental impact of production and trade. Production is assumed to operate under cost minimization with perfect markets and constant return to scale technology. The sector-level production technology is specified as nested Constant Elasticity of Substitution (CES) production functions in a hierarchy as exposed in Figure 1.

FIGURE 1: PRODUCTION STRUCTURE OF A GENERIC SECTOR IN ENV-LINKAGES



Source: Chateau, Dellink and Lanzi (2014).

The model adopts a putty/semi-putty technology specification, where substitution possibilities among factors are assumed to be higher with new vintage capital than with old vintage capital. In the short run, this ensures inertia in the economic system, with limited possibilities to substitute away from more expensive inputs, but in the longer run this implies relatively smooth adjustment of quantities to price changes. Capital accumulation is modelled as in the traditional Solow-Swan neo classical growth model.

International trade is based on a set of regional bilateral flows. The model adopts the Armington specification, assuming that domestic and imported products are not perfectly substitutable. Moreover, total imports are also imperfectly substitutable between regions of origin. Market goods equilibria imply that, on the one side, the total production of any good or service is equal to the demand addressed to domestic producers plus exports; and, on the other side, the total demand is allocated between the demands (both final and intermediary) addressed to domestic producers and the import demand.

The long-term profile of aggregate productivity and value-added for all major countries and regions is determined by the long-term growth model, but the environmental module determines the change over time in production structure and trends in trade specialization across the sectors included in the model (Table 1). More specifically, some sectors in some countries take advantage of comparative advantage associated with the change in endowments of production factor inputs or in their efficiency of use relative to other factors. This explains that changes in production patterns do not necessarily correspond to changes in demand and partly reflect changes in trade specialisation patterns.

TABLE 1: PROPOSED SECTORAL AGGREGATION OF ENV-LINKAGES FOR THE PLASTIC OUTLOOK FROM GTAP10 DATABASE

Agriculture, fishing and forestry	Non-manufacturing industries	Manufacturing	Services
Paddy rice	Coal extraction	Food products	Land transport
Wheat and meslin	Crude oil extraction	Textiles	Air transport
Other grains	Natural gas extraction and distribution	Chemicals	Water transport
Vegetables and fruits	Other mining	Rubber and plastics	Business services
Oil seeds	Petroleum and coal products refining	Pharmaceutical products	Non-business services (government…)
Sugar cane and sugar beet	Electricity transmission and distribution	Iron and steel	
Fibre plants	Electricity generation (7 technologies[#])	Pulp, paper and publishing products	
Other crops	Water and waste collection and distribution	Non-metallic minerals	
Livestock	Construction	Motor vehicles	
Forestry		Non-ferrous metals	
Fisheries		Electronic equipment	
		Fabricated metal products	
		Wood products	
		Other transport equipment	
		Other machinery equipment	
		Other manufacturing	

Note: Electricity generations: Nuclear Electricity; Hydro (and Geothermal); Solar &Wind; Coal-powered electricity; Gas-powered electricity; Oil-powered electricity; Other (combustible renewable, waste,...).

2.2. Enhancements of ENV-Linkages for the Global Material Outlook

2.2.1. Ongoing improvements

The ENV-Linkages model is currently being enhanced for this study with key features to allow for the modelling of plastic production and waste flows, as well as the policies to address environmental issues (represented in red in Figure 2).

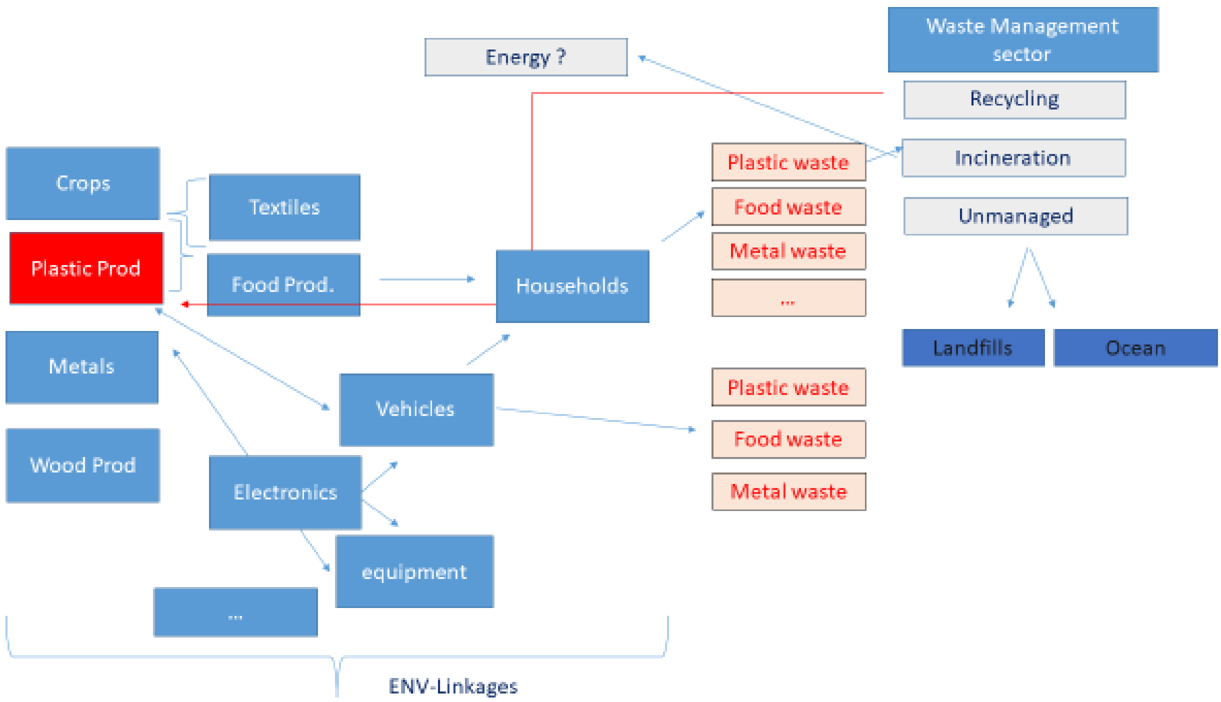
A first enhancement will be the representation of "rubber and plastics products" production, use and trade. To do so, this sector is currently being isolated in the underlying social accounting matrix to represent both the inputs to this production, as well as the demands for plastics driving its production. This first steps allows on the one hand to represent the substitutions between the various feedstocks to produce plastics (including secondary plastics or biodegradable plastics) and on the other hand to represent the substitutions in uses between materials. For instance, a better representation of input demands of the textile sector (between crops/livestock/ and non-agriculture based inputs including plastics) could allow to model the shift in materials used for textiles. Another interesting sector is the food industry sector, which uses a significant amount of plastics, but could revert to substitutes such as glass, paper, or use more environmentally friendly plastics.

2.2.2. Possible and desirable improvements

First, the waste management sector could be isolated (depending on data availability and parternship elaboration). The representation of economic activities related to plastic reuse and recycling hinges around the representation of this sector. The waste management sector collects and processes waste in several ways: recycling, incineration, landfilling. The waste that is not managed is lost in the environment and maybe end up in rivers and oceans. Therefore, representing the various management systems, their evolutions and the key determinants of their dynamics is essential in measuring key aspects of the environmental impacts of plastics.

Second, the ENV-Linkages model can be complemented by extended bottom up models of plastic waste generation.

FIGURE 2: ENHANCEMENTS OF THE OECD ENV-LINKAGES MODEL



Section 3 describes in detail a possible route to better represent plastics production, while Section 4 describes the possible modelling of plastic waste management.

3. Modelling production and consumption

To model plastics consumption (use), two main sources of data exist:

- Data on plastics production and consumption by economic sector by GTAP10 for one generic plastic for 2011 and 2014 (all in monetary values)
- Regional flows of plastics and global application-specific flows of plastics (all in tons).

A mapping could be done between the different applications of plastics and the economic sectors in GTAP. For the moment, given the lack of regional details, one could assume an identical repartition across sectors or link it with the sizes of the sectors in GTAP10 to match monetary and physical flows. These initial values are calibrated using data from Ryberg et al. (2019), combining polymer distribution by application (global) with distribution of total plastics use by region and application. With the assumption that the polymer distribution applies homogenously, we build a matrix. The additional crucial assumption is mapping between uses and sector, for instance where is packaging?

Based on the initial picture in 2014, **plastics use** will be projected following the flows of "rubber and plastics products" into the various corresponding demand sectors (food products, construction), from initial values, following the methodology developed for the Global Material Resources Outlook (OECD, 2019). In particular, the model will incorporate a series of plastics chains from initial production to final demand, either partially or in full depending on the particular structure of each economy. The basis for the chain would include flows from "oil" or "biomass" to "chemicals", that are then used for the production of "plastic products" which serve as intermediates goods or different sectors such as food product/appliances/motor vehicles/construction, before reaching final demand. The underlyingly (strong) assumption here is the fact that the coefficient linking monetary flows to physical flows (in tons) is kept constant, but adapting this assumption requires data analysis in the past that may be impossible for lack of data. **Plastics production** will then follow these demands, based on trade flows and plastics use.

In addition to plastics production and use, each step of the plastic chains comes along with the a certain amount of **plastics waste** and its corresponding **environmental damages**. These flows of plastic waste and environmental damages will be mapped explicitly across the value chains.

4. Waste generation and waste management modelling

Using the available data sources, one proposed approach to model **plastic waste management** within ENV-Linkages is depicted in the chart below. Sources of available data include 4 sources on plastic waste and mismanaged plastic waste at the country and global level: Lebreton and Andrady, 2019; Jambeck et al., 2015; Gómez-Sanabria et al., 2018; Geyer, Jambeck and Law, 2017.

Using projections for plastic waste and assuming a relation between plastics' production and waste, we can dynamically calibrate ENV-Linkages. There are three main questions to tackle:

- How to connect production process and waste production?
- How to connect commodity demand/uses and consumption waste
- How to disaggregate plastics production and plastics waste to primary and secondary?

Suggested modelling framework:

- Express primary waste as a function of plastics production (in volumes), following (Geyer, Jambeck and Law, 2017) methodology using lifetime distributions.

This could be be linked to the waste management sector in ENV-Linkages. To do so, we need to split the waste sector from the water sewerage management in GTAP 10. Then, maybe add to this sector the demand for a natural resource linked to the plastics waste quantity.

Primary Plastic waste (PW) in year *t* is equal to sum across years and sectors of plastic produced at year *t-j* * probability that plastic in sector *i* is discarded in *j* years.

$$PW(t) = \sum_{i\ sectors} \sum_{j\ years} P_i(t-j) * LTD_i(j)$$

where:

$P_i(t)$ – denotes the amount of primary plastics in year *t*, sector *i*.

t = {1950,…, 2015} or available data

i = {packaging, consumer & institutional products, other and textiles, electrical & electronic, transportation, industrial machinery, building and construction}

$LTD_i(j)$ – Product lifetime distributions, for 8 sectors for j years

$j = \{1,\ldots, 65\}$

Further work is needed to (i) map sectors i to the GTAP database, and (ii) update the product lifetime distributions based on the lastest available data.

- Express secondary plastics waste as a share of delayed production following (Geyer, Jambeck and Law, 2017) methodology and using updated data recycling rates from IEA (if possible):

Secondary Plastic Waste (SW) in year *t*

$$SW(t) = [PW(t-k) + SW(t-k)] * RR(t-k)$$

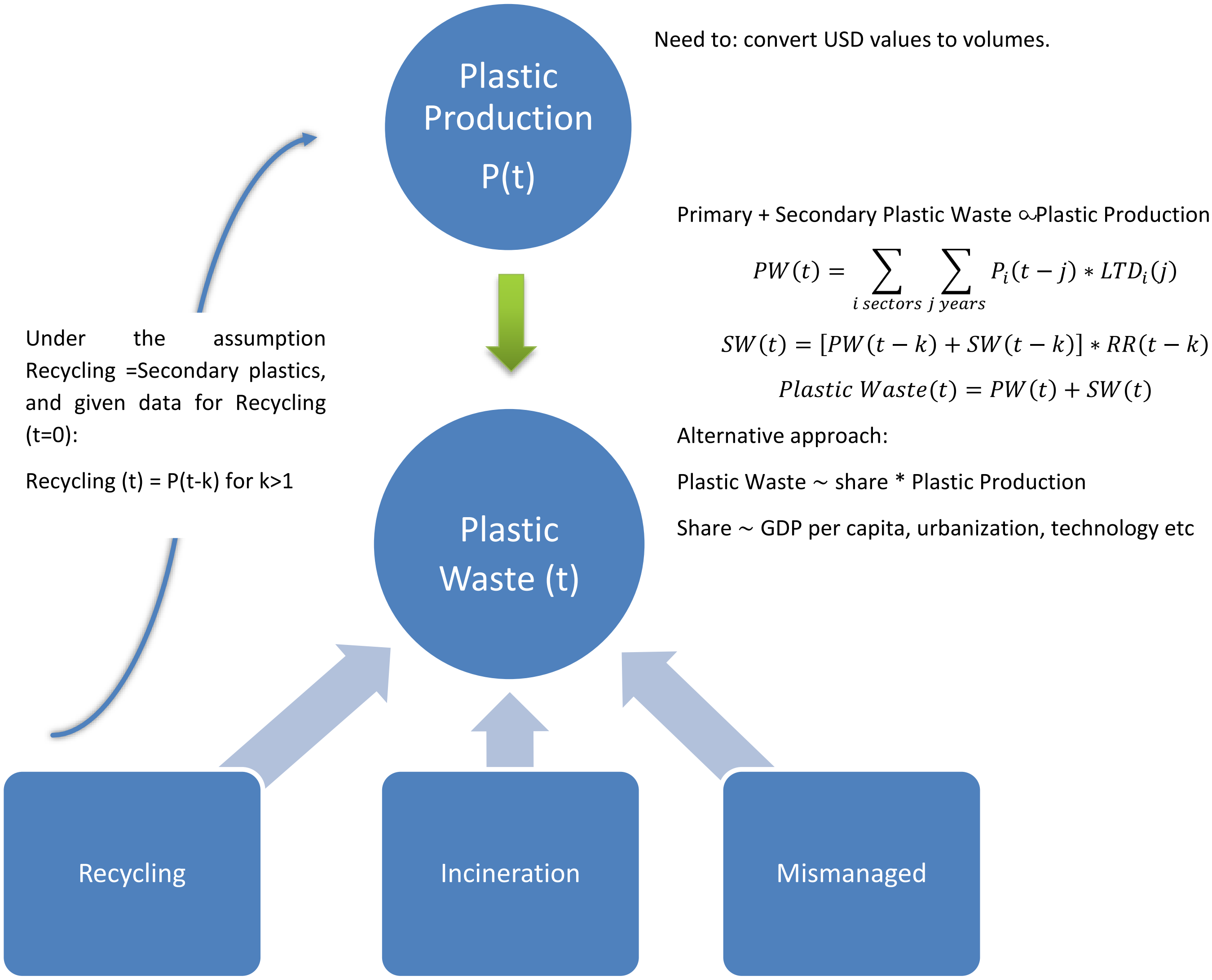
where:

k - the average use time of secondary plastics

RR(t-k) – the global recycling rate in year *t-k*

  - Plastic waste can be divided into three categories: recycling, incinerated waste and mismanaged waste. In this framework, secondary plastic waste would correspond to recycling. To distinguish between the other two categories, we can use estimations on the share of mismanaged waste from Jambeck et al. (2015) or Lebreton and Andrady (2019).

FIGURE 3. PLASTICS MODELLING IN ENV-LINKAGES



5. The link to policies and steps fowards

The ENV-Linkages model is designed to explore the impact of policy mixes on a range of environmental issues, including the phasing-out of fossil-fuel subsidies, raw material tax, pricing of GHG emissions and other energy policies.

For this project, measures targeting plastics, such as mandatory recycled contents or some plastic use regulations may be integrated if relevant information is available. Measures with budgetary implications can be fully taken into account and offset through changes in the tax or spending structure of public accounts. The model can also be used to study the impact of regulatory or technology-enhancing measures to promote greener modes of production and growth. As a by-product of its structure and scope, the model can also be used to explore more sector-based or trade-related measures, although in this case the link from policy to outcome may be less direct.

To summarise, this framework can allow us to study:

- Policies that affect the production of plastics directly at the aggregate and sectoral level
- Policies that affect the share of mismanaged waste of plastics by changing:

- the product lifetime distributions
- the average proportion of plastic in solid waste
- the incineration and discard rates

Additional (open questions) to consider would include:

- How to best model the role of plastic waste trade in the absence of relevant data?
- What is the releveant importance (or not) of modelling different types of plastic good/technologies?
- How to model and what are the benefits of explicitly modeling recycled and biodegradable plastics?
- What alternative non-market based policies to consider?