Modelling plastics use and waste in a CGE: Methodology and baseline projections to 2060

Ruben Bibas*, Daniel Ostale Valriberas*, Elisa Lanzi*

* OECD.

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Abstract

Plastics are extremely useful materials for modern society, but plastic production and waste generation continue to increase with increasing environmental impacts despite international, national and local policy responses, as well as industry commitments. Despite calls for international action and the launch of international negotiations, the global community is far from achieving it objective if eliminating plastic pollution unless more stringent and co-ordinated policies are implemented. This paper provides a forward-looking perspective, presenting a set of coherent projections on plastics to 2060, including plastics use and waste to allow for a better understanding of the environmental benefits and economic consequences of adopting stringent policies. This paper focuses on ASEAN Plus Three (APT) countries, as APT has arisen as a hotspot for plastic pollution (around 30% of global plastic leakage to the ocean originates in the APT region), because of rising living standards, fast-paced urbanization and an infrastructure for waste management that is not yet equal to the needs. Furthermore, regional and cross-border coordination is particularly important in this region given shared rivers and coastlines, as well as regional markets for plastics and plastic waste. Many APT countries are already prioritizing actions to combat plastic pollution. For instance, the ASEAN released the Bangkok Declaration on Combating Marine Plastics in 2019.

Context

Plastics are one of the most commonplace materials on the planet. In 2015, global plastics production reached 407 Mt, surpassing that of paper (400 Mt)[1] and aluminium (57 Mt).[2] If growth persists at similar rates, plastics production is expected to reach 1600 Mt in 2050 (EMF, 2017). The extraction of materials for plastics production, and the use and disposal of plastic products is creating significant environmental pressure, with consequences for ecosystems and health. One apparent environmental impact is the ubiquitous plastic pollution, especially plastic litter in the oceans. 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 Mt are estimated to be introduced every year to the oceans (Jambeck, et al., 2015). This material will only decompose over the course of hundreds of years.

Projections of plastic use already exist in the published literature (Geyer, et al., 2017; Lebreton, et al., 2019; Gomez Sanabria, et al., 2018; EMF, 2017). However, they are generally linked to projection of the whole economy (without sectoral distinction), 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 presents both the methodology to incorporate flows of plastic use and waste in a CGE model and the ensuing baseline to 2060, created with a dynamic computable general equilibrium (CGE) model (the OECD 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 naive projections do. This paper builds on modelling methodology developed for material projections of the OECD Global Material Resources Outlook (OECD, 2019). In this perspective, this paper take advantage of the

[1] WWF (2018), Pulp and paper.
[2] USGS (2016), Aluminum Legislation and Government Programs.

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new GTAP10 database split of the “Chemical, rubber, plastic products (crp)” sector into 3 new sectors, including plastic. The objective of the paper is to improve knowledge and projections of the economic drivers of the production and use of plastic to support better policymaking that aims at sustaining economic growth while improving environmental quality.

Methods

The broad structure of the ENV-Linkages model

The ENV-Linkages model is a computable general equilibrium (CGE) model based on the GTAP national accounting database (Chateau, et al., 2014). It describes the interactions of economic activities for different sectors and regions. 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.

Modelling plastic production and consumption

To model plastics consumption, two main sources of data need to be reconciled: (i) plastics production and consumption by economic sector (all in monetary values) and (ii) regional flows of plastics and global application-specific flows of plastics (all in tons). Table 1 summarises the different steps in the modelling. A mapping was done between the different applications of plastics and the economic sectors in GTAP10.

Volumes of primary plastics for 2015 rely on data from Ryberg at al. (2019), that updates and expands on the seminal work in Geyer, Jambeck and Law (2017). Since the estimates from Ryberg et al. (2019) were provided on the one hand by region and application, and on the other hand by application and polymer, an assumption of homogeneity of polymers by application was taken to estimate plastic use by region, polymer and application.

Secondary plastics volumes for 2015 were estimated following a methodology deriving secondary plastics through waste collected for recycling and recycling losses, using a fixed-point methodology. Loss rates including sorting losses and reprocessing losses were estimated using a methodology developed by the University of Leeds based on a review of the literature.

The base-year estimates of plastics use are complemented with plastics use for the past between 1950 and 2014, for two reasons. The first reason is to be able to accurately compute waste flows in the future, since plastic lifetimes can span up to decades. The second reason is to form the basis for the computation of environmental impacts, as for instance plastic leaked in the ocean accumulates over time.

Based on the initial picture in 2014, plastics use will be projected for a baseline scenario, following the flows of “rubber and plastics products” into the various corresponding demand sectors, from initial values, following the methodology developed for the Global Material Resources Outlook (OECD, 2019). This “Manufacture of rubber and plastics products (RPP)” sector was split into two production technology: primary production (which includes fossil fuel based and biobased plastics). 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 underlying (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.

Table 1: Modelling steps details

Step	Details
Drivers of plastic demand	Project sectoral and regional economic developments with the ENV-Linkages model
Plastic volumes	Associate plastic volumes to sectoral demand in ENV-Linkages
Plastic waste	Calculate waste flows relying on product lifetime methodology

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Plastic waste management	Break down waste by waste management (recycled, incinerated, discarded – into sanitary landfilling and others)

Economic baseline

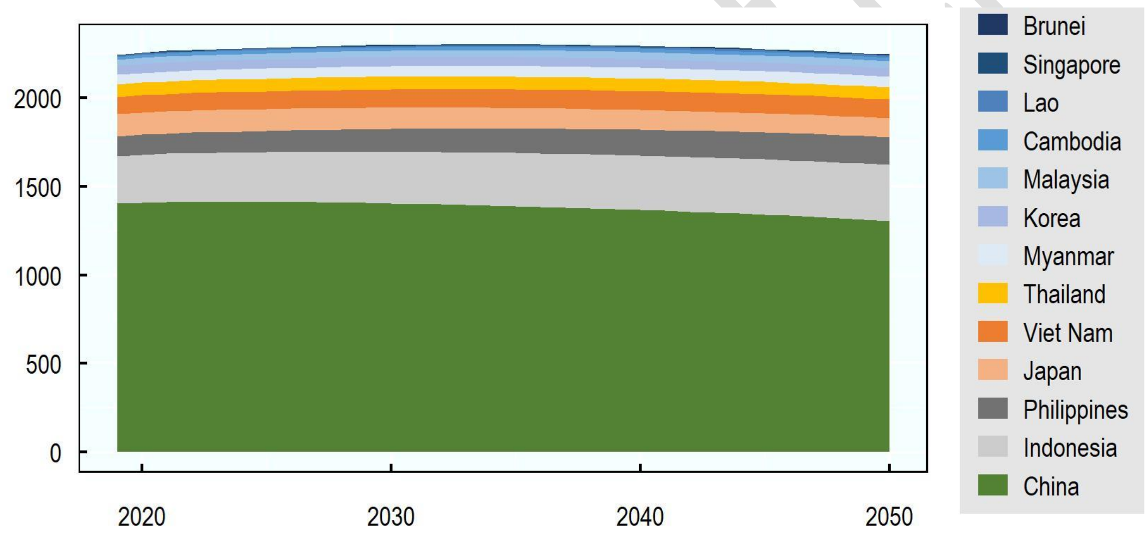
APT population will stabilize over the next decades, reducing its global share

Population in the ASEAN Plus Three (APT) region is projected to grow until the mid-2030s, reaching a total of 23 billion people (Figure 1). After that date, population will decline by 2% between 2030 and 2050 regressing to 2019 population levels. As a result, the proportion of APT in the global population will decline from 29% in 2019 to 23% in 2050.

These regional trends hide significant differences in demographic growth rates among individual countries. By the middle of the century, the population of the Philippines, Laos, Malaysia, and Cambodia is projected to increase by more than 25%, while the populations of China, Korea, and Japan are expected to decrease by 7% (China), 11% (Korea), and 17% (Japan).

Figure 1: Population undergoes different dynamics in APT countries

Population in millions.

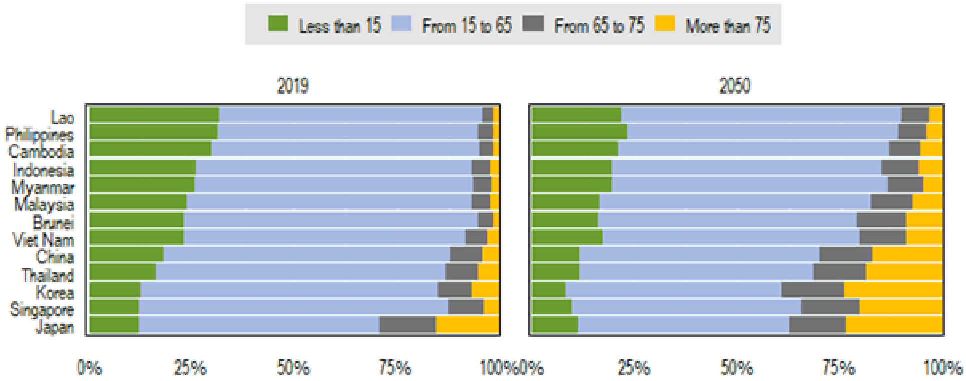


Source: UN Population data (2022).

Although the overall population levels are expected to remain similar between 2019 and 2050, significant changes in population composition are anticipated (Figure 2). Working age population is projected to decrease from 69% to 60% by 2050. In 2019, a fifth of the APT population was under 15 years old and 11% over 65. By mid-century, the percentage of individuals under 15 is expected to decrease to 15%, while the proportion of those over 65 is projected to increase to 26%. In Korea, China, Singapore, and Thailand, one in four people will be over 65 in 2050.

Figure 2: Change in population composition

Share of population by age range.



Source: UN Population data (2022).

Economic growth will improve living standards in all ASEAN countries

Global living standards are projected to improve by 2050, especially in the APT region, where GDP per capita will reach 2.4 times current levels (Figure 3). Cambodia is expected to experience the highest relative growth in GDP per capita at 3.4 times its current level, followed by Vietnam (3.2 times) and Philippines (2.8 times). Singapore and Brunei which already have high GDP per capita, are expected to continue growing at a moderate rate, reaching over 95 thousand USD per capita by mid-century.

Figure 3: Living standards are projected to increase

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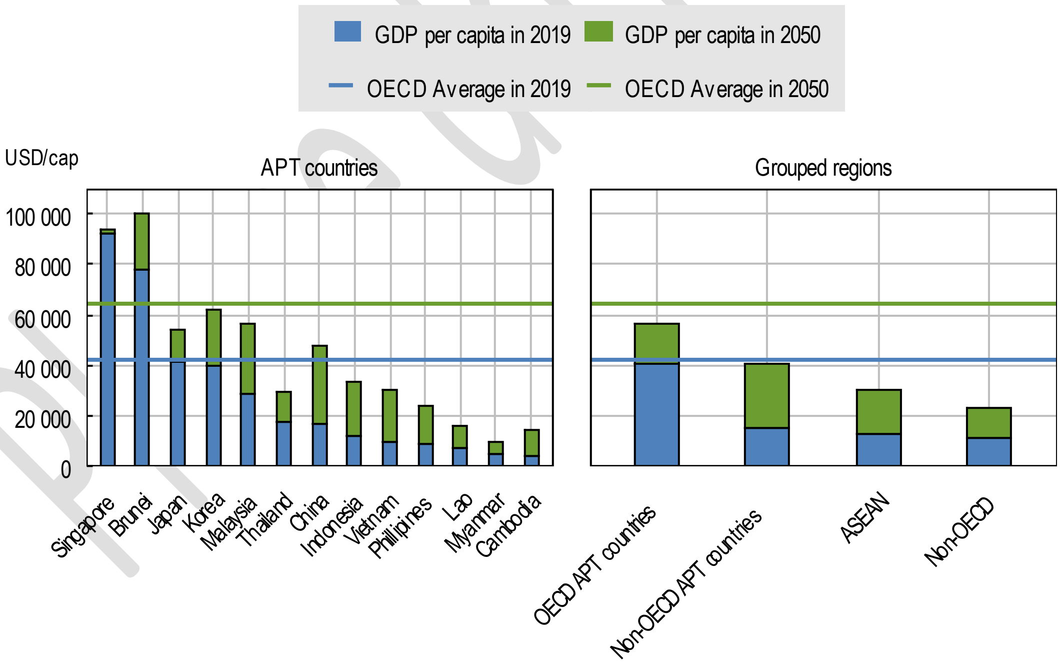


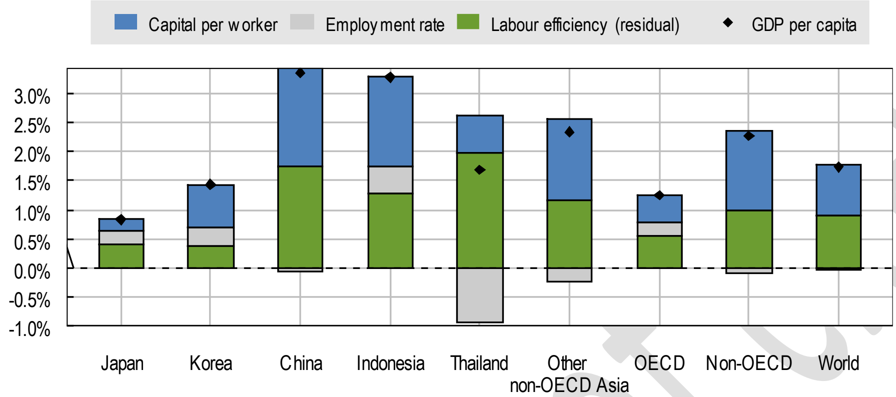
Source: OECD Long-term model and OECD ENV-Growth model.

Non-OECD APT countries are projected to reach the same level of GDP per capita as OECD countries today on average (Figure 3). Comparing ASEAN countries with non-OECD countries, the projection shows that although they start from a similar level in 2019, GDP per capita will grow faster in the ASEAN region. The OECD APT countries, however, are projected to grow more slowly than the OECD average.

The GDP changes are mainly driven by the evolution of the main primary factors of production (capital and labour) as well as by technical progress. These changes can come from a wide range of drivers, including continued efforts to optimise existing production processes, adopting new business models, and the spreading of best available techniques. The change in GDP per capita can be broken down into changes in employment levels, in labour efficiency and in the amount of capital per worker (Figure 4).

Figure 4: The drivers of growth are heterogenous

Contribution of each factor to growth between 2019 & 2050, all in percentage points.



Note: The changes in the GDP per capita in market exchange rates (y) are decomposed in three components: (i) the change in employment rate (ER), (ii) the change in capital per worker (where capital is defined in a broad way including land and natural resources) (k), and, as a residual factor, (iii) the change in labour efficiency (A). Changes in GDP (in market exchange rates) can be decomposed as in the following formula: $\frac{\Delta y}{y} = \alpha \frac{\Delta A}{A} + (1-\alpha)\frac{\Delta K}{K} + \frac{\Delta ER}{ER}$ where α is the share of labour income in GDP. The GDP per capita growth rate in market exchange rates differs from the one in PPP exchange rates as the weights of different countries in regional aggregates differ.
Source: OECD ENV-Linkages model.

Global GDP is expected to grow steadily but at a slower pace in the coming decades (Figure 5). Non-OECD countries are expected to lead this growth with annual growth rates of 3.2% while OECD countries will grow at 1.7%. APT countries increase their GDP by 2.8% annually, led by Cambodia with growth rates above 4.7%. Philippines, Vietnam, Indonesia, Laos, and China will see an annual GDP growth of more than 3%. Overall, APT countries will account for more than half of the world economy, growing their importance from 48% to 51% in 2050.

Figure 5: Global GDP is projected to grow more slowly, with a growing share for APT

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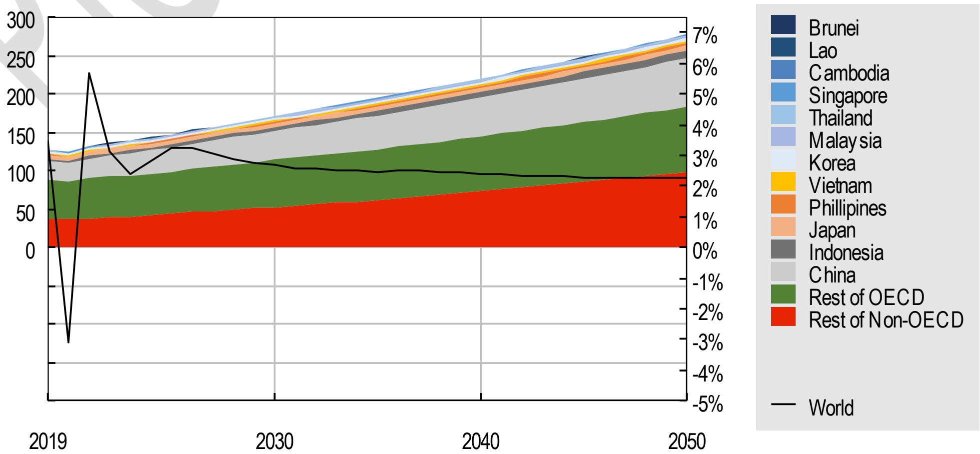

Source: OECD Long-term model and OECD ENV-Growth model.

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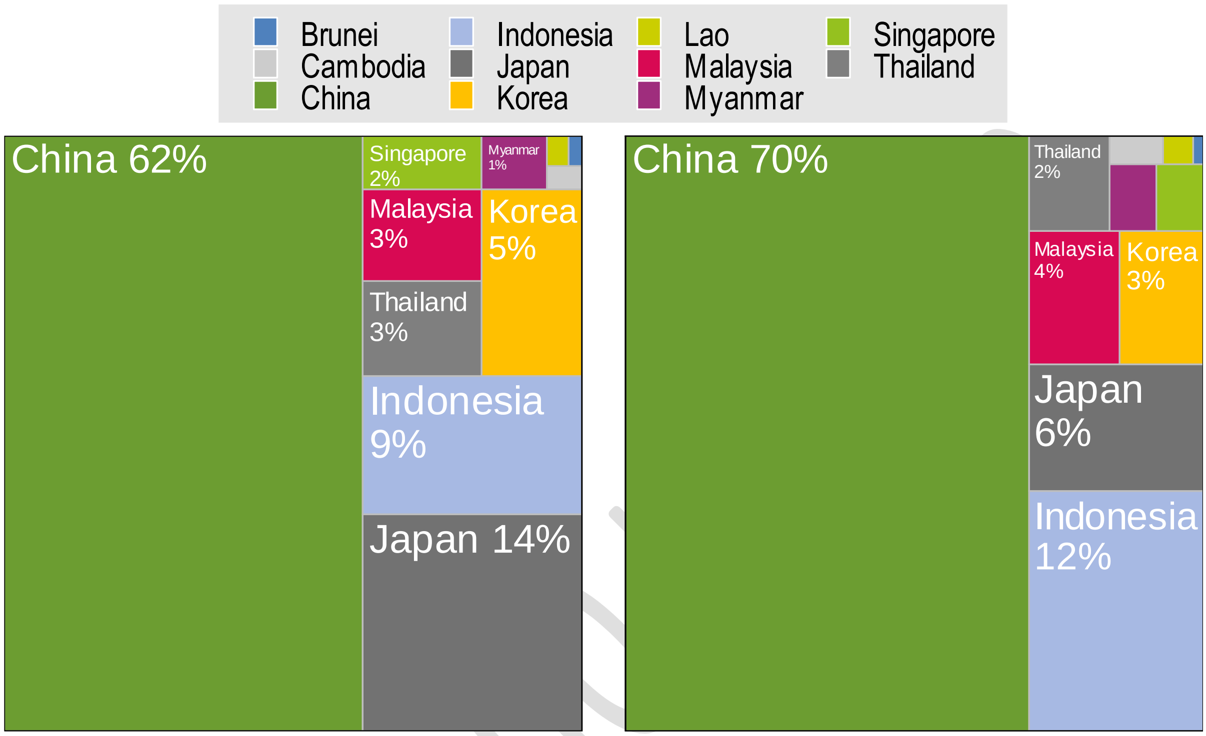
Differences in economic growth among the APT countries imply that distribution of GDP in the region will change over the coming decades (Figure 6). China will not only continue to grow its GDP (Figure 5), but will also its importance in the region, reaching 70% of the overall APT economy. OECD countries, with lower growth rates than the rest of the region, will decline in importance, with Japan accounting for only 6% of the region in 2060.

Figure 6: The regional distribution of GDP will change in the following decades



Source: OECD Long-term model and OECD ENV-Growth model.

Services will represent an increasing share of the global economy

With the growth of the APT economies, the services sector is becoming increasingly dominant (Figure 7). In OECD countries, economies shift from business-related services towards 'other services', which includes education, health, and social services. In non-OECD countries, two trends are occurring simultaneously. there is growth in business-related tertiary sectors such as insurance and real government services across all countries. In parallel, within industrial sectors, there is a shift away from traditional sectors such as iron and steel, construction, and mineral extraction towards those related to transport, electronics and the manufacture of machinery and equipment.

Figure 7: Depending on the growth stage of the country, the sectors showing largest growth are industry or services

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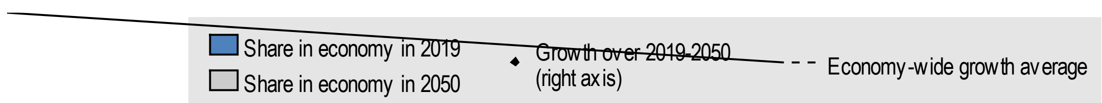
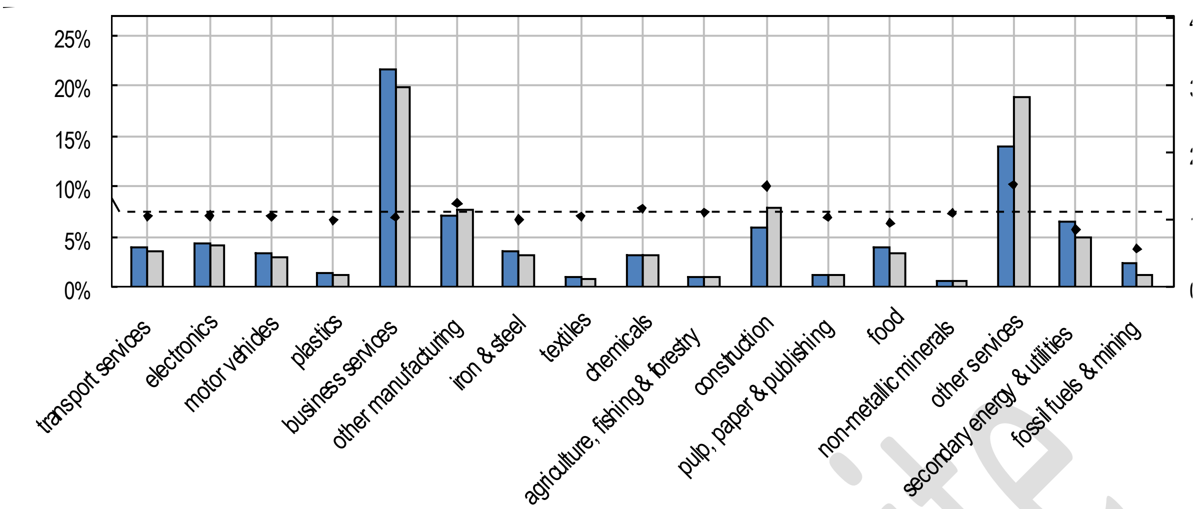
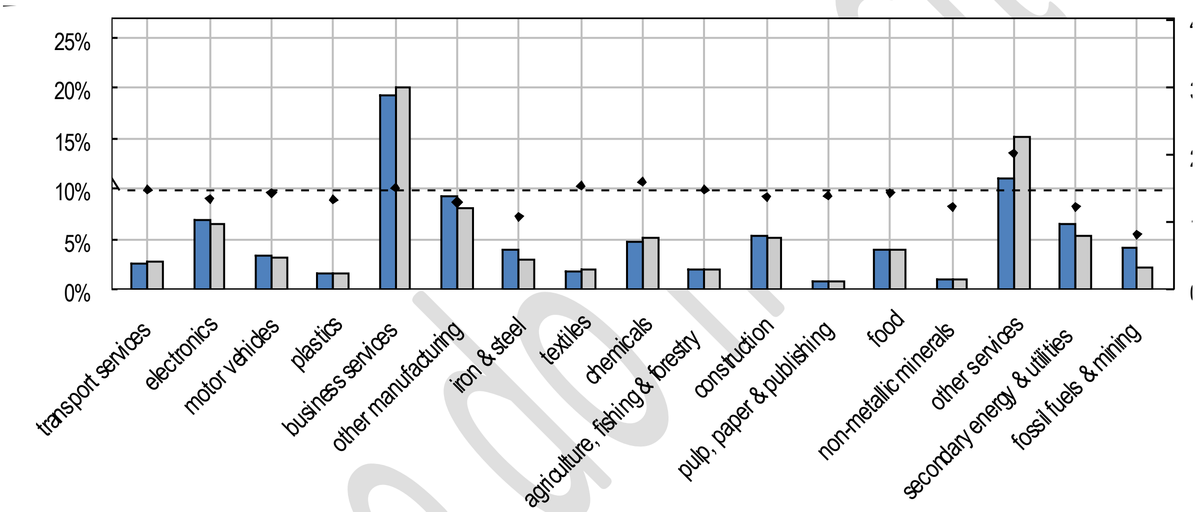


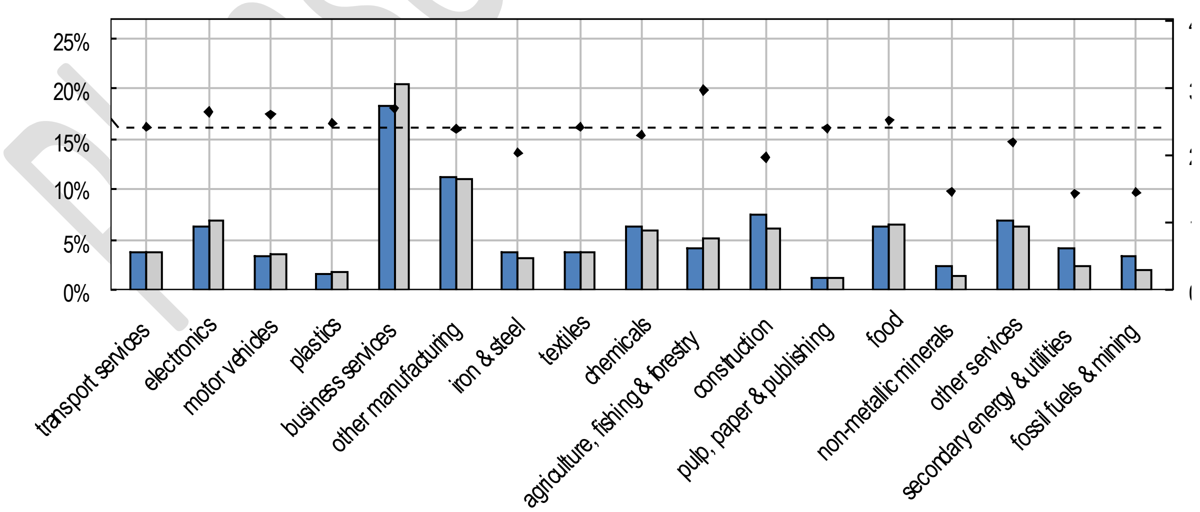
Japan



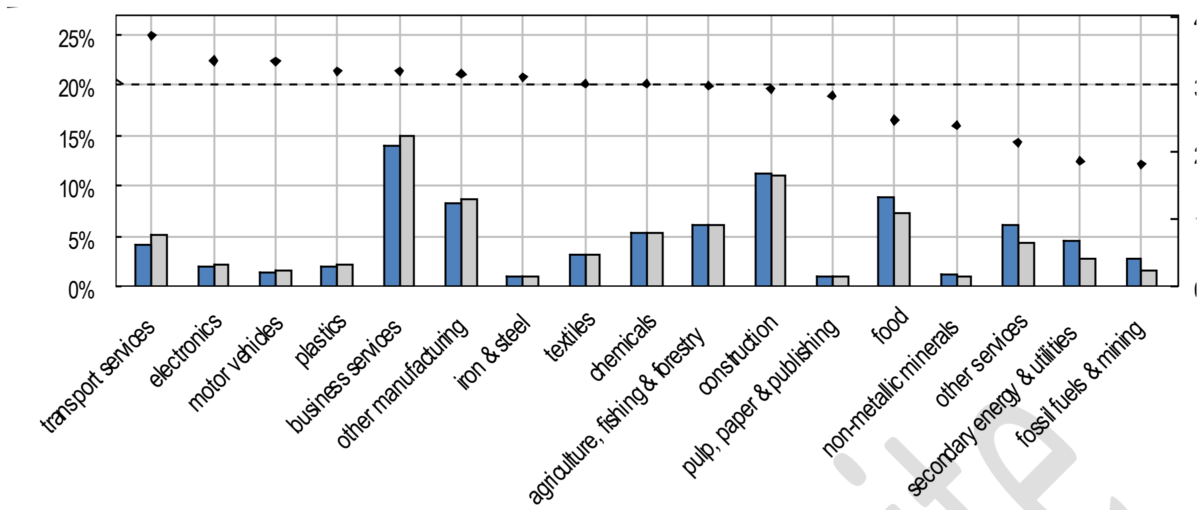
Korea



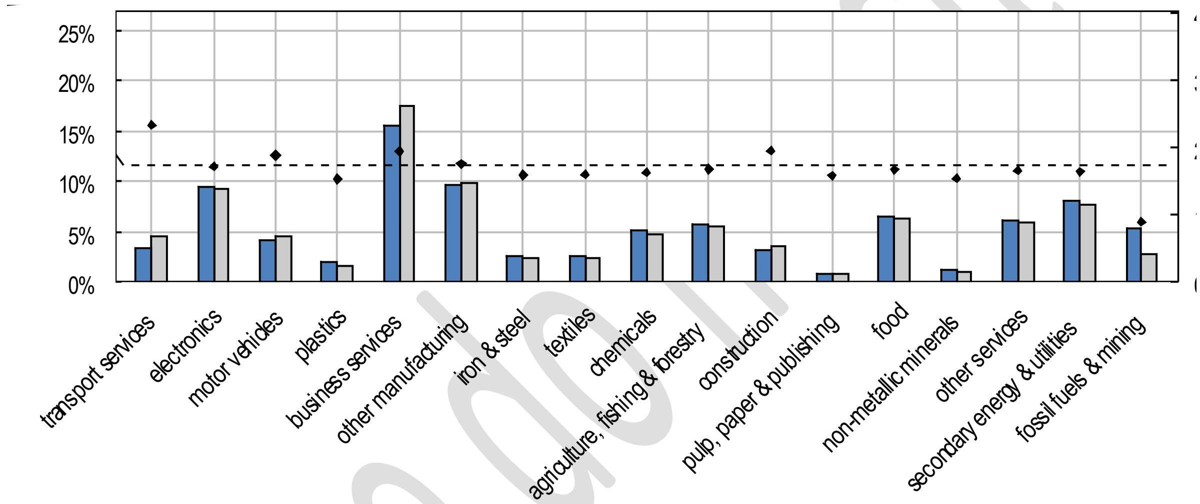
China



Indonesia



Thailand



Source: OECD ENV-Linkages model.

Drivers of plastic use [to be completed]

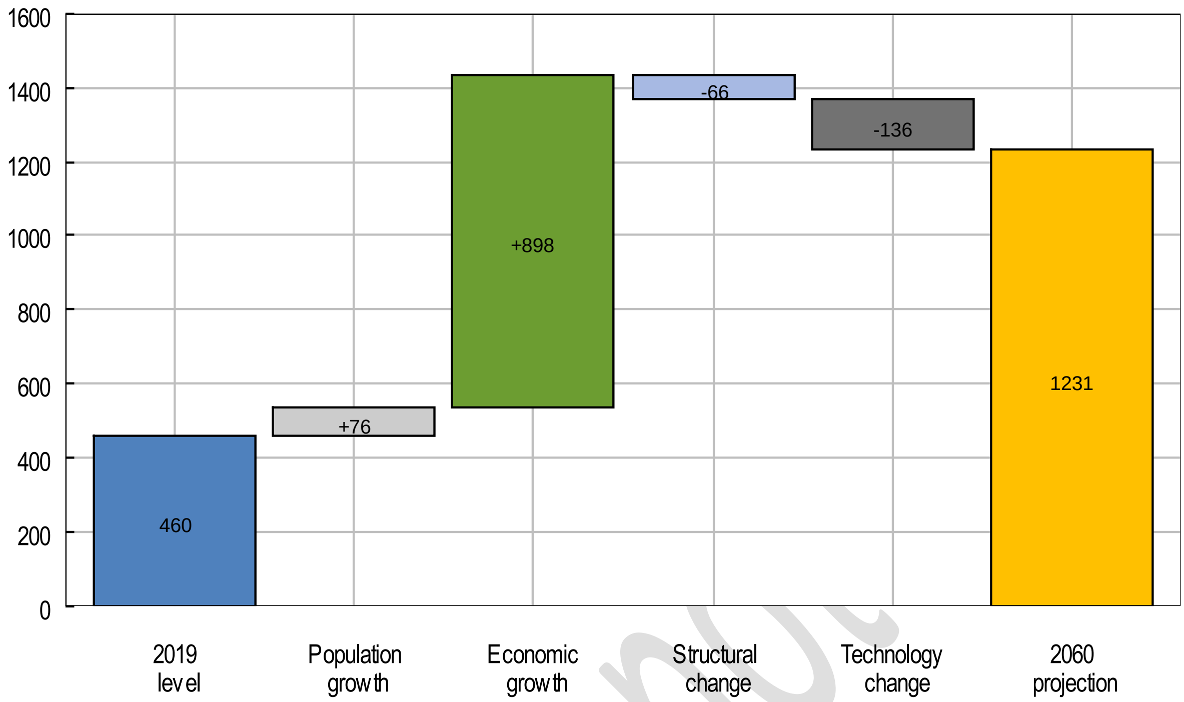
Economic growth is the main driver of plastics use

Global plastics use is projected to almost triple between 2019 and 2060 in the *Baseline* scenario, increasing from 460 million tonnes (Mt) to 1 231 Mt yearly (Figure 8). In this scenario, continued socioeconomic developments and economic growth, including recovery from the COVID-19 pandemic (Chapter 2), see emerging and developing economies catch up with higher income countries.

The projected increase in plastics use is mostly driven by economic growth: more economic activity means more use of plastics, in production and consumption. With global GDP more than tripling between 2019 and 2060, this effect is very strong. While rising income levels lead to a rapid increase in plastics use (to 898 Mt in 2060, shown by the green bar in Figure 8), other socio-economic factors also increase the use of plastics. Population growth also leads to an increase in plastics use (light grey bar; +76 Mt). However, its effect is limited because per-capita plastics use is relatively low in the regions with the fastest population growth, most notably Sub-Saharan Africa. This growth in plastics use will be moderated by changes in the structure of the economy, most notably a shift towards services (purple bar; -66 Mt), and the use of more efficient technologies in production processes (dark grey bar; -136 Mt), which lower the amount of plastics used per dollar of output of plastic-using commodities.

Figure 8: Plastics use is projected to almost triple, mostly driven by economic growth

Decomposition of the increase of plastics use between 2019 and 2060 in million tonnes (Mt), *Baseline* scenario

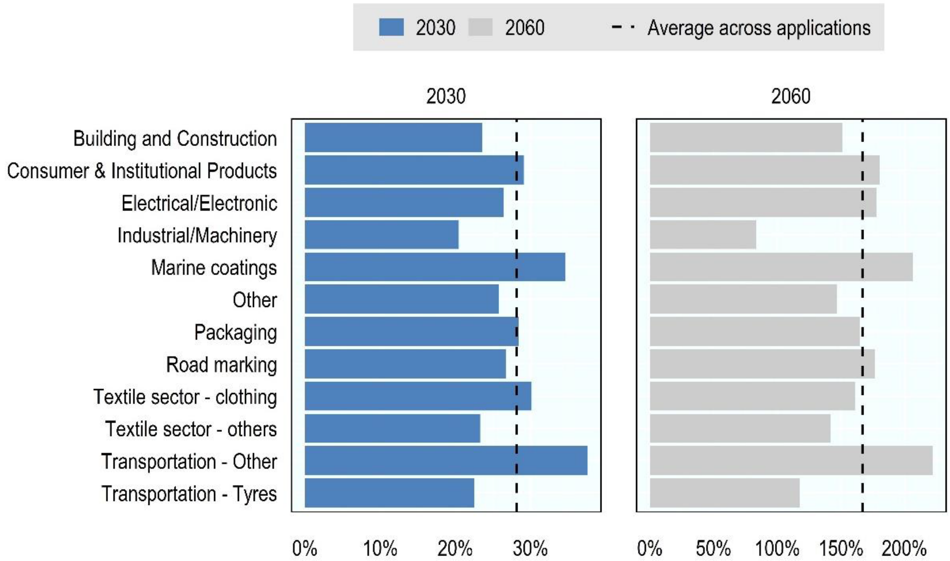


Notes:
Population growth represents a projection in which plastics use is assumed to grow at the same speed as population and in which the regional plastics use per capita stays constant at 2019 levels.
Economic growth represents a counterfactual projection in which plastics use is assumed to grow at the same speed as GDP and in which the regional plastics intensity (the amount of plastic per unit of output) stays constant at 2019 levels.
Structural change identifies the contribution of sectoral shifts to reducing global plastics use by differentiating sectoral growth rates.
Technology change identifies the contribution of technology improvements to reducing global plastics use by differentiating growth rates of plastic inputs to sectoral output. Technology change not only includes technological improvements but also a wider diffusion of existing technologies.
Source: OECD ENV-Linkages model.

Projections of plastic flows

Plastics consumption is projected to increase across all application by 2060 (see Figure 9). The largest growth can be observed in Transportation equipment (Transportation – Other). The categories Marine Coatings and Road Markings undergo a similar high growth. Albeit small in tons, those categories are important are they are a large source of microplastics in the environment. The bulk of plastics consumption (such as Building and construction, Consumer and Institutional Products) also undergo a strong growth.

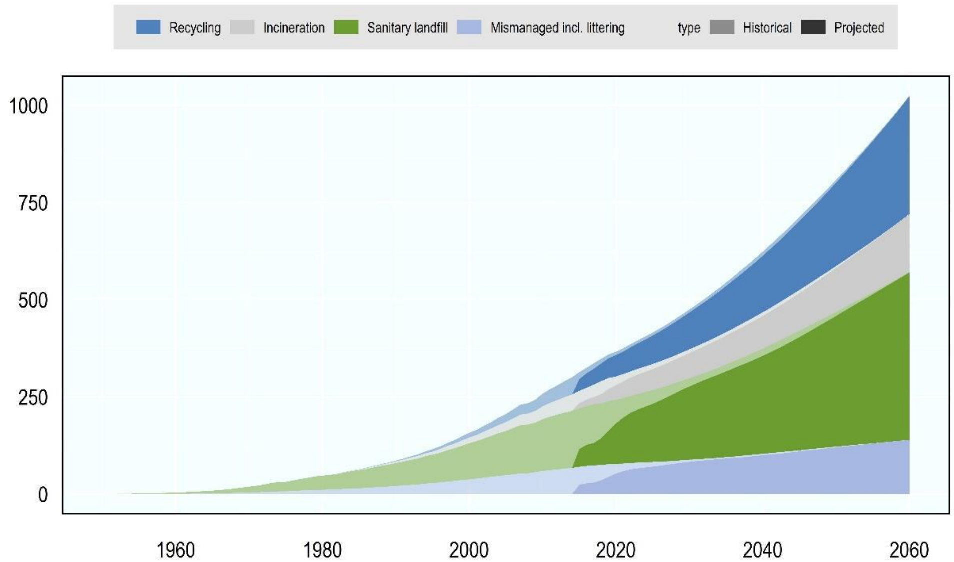
Figure 9: Growth of projected plastic consumption by application



Source: OECD ENV-Linkages model, preliminary results (please do not cite or quote).

As a consequence, plastic waste is projected to almost triple by 2060 and reach 1025 Mt (see Figure 10). While the share of recycling is projected to increase, a significant share of plastic waste is still incinerated or landfilled by 2060. The share of mismanaged plastic waste keeps increasing despite better waste management; implying an increasing amount of plastics lost in the environment.

Figure 10: Projected plastic waste management



Note: flows for the 2015-2050 period in full colour, historical in light colours.
Source: OECD ENV-Linkages model, preliminary results (please do not cite or quote).

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