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JEL Classification: H23, Q51, Q52, Q53

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Abstract

This paper provides estimates of the cost of preventing land-based plastic leakage into the ocean, covering 38 OECD member countries and 10 selected major plastic waste emitters in Asia and Africa. The study estimates capital costs at EUR 54 billion in the Moderate Ambition s cenario and EUR 74 billion in the High Ambition scenario. The annualised per-capita costs range between EUR 0.2 to 6.5 in the Moderate Ambition scenario and from EUR 0.8 to 6.5 in the High Ambition scenario. These cost estimates are much lower than UNEP and ISWA estimates of the cost of inaction of inadequate waste management, roughly USD 9 to 45 per capita. Differences in estimated costs are found to depend on countries' waste policy stringency and waste management infrastructure. This paper contributes to OECD work in support of a sustainable ocean economy and the Global Plastics Outlook report.

Keywords: marine litter, plastic, leakage, waste management, circular economy, extended producer responsibility, product stewardship, resource efficiency, sustainable consumption

JEL Classification: H23, Q51, Q52, Q53

Résumé

Ce document fournit des estimations du coût de la prévention des rejets de plastique d'origine terrestre dans le milieu marin, couvrant 38 pays membres de l'OCDE et 10 principaux émetteurs de déchets plastiques sélectionnés en Asie et en Afrique. L'étude estime les coûts en capital à 54 milliards d'euros dans le scénario d'ambition modérée et à 74 milliards d'euros dans le scénario d'ambition élevée. Les coûts annualisés par habitant varient entre 0,2 et 6,5 EUR dans le scénario d'ambition modérée et entre 0,8 et 6,5 EUR dans le scénario d'ambition élevée. Ces estimations de coûts sont bien inférieures aux estimations du PNUE et de l'ISWA du coût de l'inaction d'une gestion inadéquate des déchets, soit environ 9 à 45 USD par habitant. Les différences dans les coûts estimés dépendent de la rigueur de la politique des déchets des pays et de l'infrastructure de gestion des déchets. Ce document contribue aux travaux de l'OCDE en faveur d'une économie océanique durable et au rapport *Perspectives mondiales des plastiques*.

Mots clés: déchets marins, plastique, rejets, gestion des déchets, économie circulaire, responsabilité élargie des producteurs, bonne gestion des produits, utilisation efficace des ressources, consommation durable

Classification JEL: H23, Q51, Q52, Q53

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In follow-up OECD work, a global cost estimate could be developed and the links between policy instrument choice and design and the effectiveness of curbing plastic waste leakage could be analysed.

Executive summary

This paper estimates the costs[1] to upgrade plastic waste management infrastructure to prevent ocean pollution from land-based, end-of-life macroplastic[2] in OECD countries and 10 selected partner countries in Asia and Africa.

The countries under review are grouped according to the stringency of their waste policy and the level of existing waste management infrastructure into four groups: High policy stringency and highly developed infrastructure (Group 1), further split into Group 1a comprising countries with high policy stringency with a circular economy focus and Group 1b comprising countries with similarly high policy stringency but still with the more linear economy approaches. Group 2 comprises countries with moderate infrastructure and moderate policy stringency, and Group 3 includes those with low to moderate infrastructure and policy stringency.

For each country, an estimation of quantities of plastic waste leakage are based on available official statistics, secondary literature and expert judgement by the authors. The paper shows that in the reviewed countries around 5.4 megatonnes per year of land-based macroplastic leaks into the ocean due to the mismanagement of municipal solid waste (MSW).

Two investment strategy scenarios are developed to evaluate the funds needed to tackle plastic leakage through both public and private investment. The Moderate Ambition scenario is based on linear economy solutions including enhanced mixed waste collection and landfilling; energy recovery and incineration and basic treatment are included in this scenario. The High Ambition scenario proposes circular economy solutions including prevention and high recycling targets based on source separation of materials leading to resource efficiency and the reduction of greenhouse gas emissions.

Both scenarios target a 100% waste collection rate and a 100% rate of controlled recovery and disposal. However, infrastructure alone is likely not enough for achieving zero plastic leakage to the ocean. Full prevention likely requires behavioural changes, shifts in production and consumption patterns and a complex set of additional public policies. The scenarios evaluate investment needs for addressing mismanaged mixed municipal waste. The focus is on investments into plastic management at the end of the value chain, including the sorting and pre-processing stages. Cost estimates include consideration of the current waste policy and infrastructure in the countries studied.

Capital costs are estimated at a total of EUR 54 billion in the Moderate Ambition scenario and EUR 74 billion in the High Ambition scenario. The annualised per-capita costs range between EUR 0.2 to 6.5 in the Moderate Ambition scenario and from EUR 0.8 to 6.5 in the High Ambition scenario. These cost estimates are much lower than UNEP and ISWA estimates of the cost of inaction of inadequate waste management, roughly USD 9 to 45 per capita.

Calculations presented show that the High Ambition scenario is more investment-intensive with investment costs ranging from EUR 6 to 26 per capita across the different country groups as compared to EUR 0.4 to 20 per capita in the Moderate Ambition scenario. For both scenarios, the lower costs occur in the higher policy stringency and infrastructure countries and the higher costs occur in the low policy stringency and infrastructure countries.

[1] The paper estimates investment costs and annualised costs. It is not a cost-benefit analysis because the benefits, including, for example, the revenues generated from recycling in the High Ambition scenario, are not included in the model.

[2] The estimations in this study consider end-of-life plastics. The estimations do not include at-sea sources, primary microplastics or leakage from production (abrasion) and consumption (littering).

While upfront capital investment costs are higher in the High Ambition scenario, in terms of annualised costs this scenario is similar as it results in some cost savings.[3] Specifically, annualised costs in higher policy stringency and infrastructure countries are similar for the two scenarios, at EUR 0.2 and 1.2 per capita in Moderate Ambition scenario for Groups 1a and 1b, respectively, while these are slightly higher, at EUR 0.8 and 1.5 per capita in the High Ambition scenario. In these countries, the rate of plastic leakage to the ocean is rather low, estimated to be 0.2 to 0.4 kg/capita/year.

In countries with moderate policy stringency and infrastructure, the High Ambition Scenario is less costly in terms of the annualised costs, at EUR 5.5, compared to EUR 6.4 in the Moderate Ambition scenario. In these countries waste generation rates are relatively high, waste streams are relatively rich with plastic and the current waste management systems exhibit higher leakage rates, estimated at around 3 kg/capita/year.

In countries where policy stringency is only moderate to low and infrastructure is low, investing in traditional waste management infrastructure for the mixed municipal waste stream is imperative. The estimated annualised costs are slightly lower for the more traditional linear investment package at EUR 6.46 per capita in the Moderate Ambition scenario as compared to EUR 6.52 in the High Ambition scenario. In these countries, waste generation rates are relatively low, but capture rate of the waste management system is also low. Therefore, the leakage rate is rather high, estimated at 1.7 kg/capita/year.

The on-going COVID-19 pandemic poses new challenges for waste management. For instance, it has increased the production and consumption of personal health-related products, resulting in an increased use of PPE, but also some other single use plastics (e.g. face masks, gloves, protective wear, containers for sanitizers). The volume of biomedical waste has also increased which adds pressure on hazardous waste management facilities to ensure its safe disposal. The pandemic has also lead to behavioural changes, such as less time spent outside and fewer large public events (which usually are a source of plastic waste). A UCL Plastic Waste Innovation Hub study estimates that in the United Kingdom, if every person used a single-use face mask per day for one year, this would generate an additional 66 000 tonnes of contaminated waste and 57 000 tonnes of plastic packaging. However, the overall impact on global plastic waste generation and its potential mismanagement are not yet clear.

[3] Benefits, including revenues from recycling are not taken into account in the evaluation of either scenario. Inclusion of benefits in the High Ambition scenario are likely to improve the economic feasibility of the High Ambition scenario compared to the Moderate Ambition scenario, however such an evaluation has not been conducted in this study.

Synthèse

Ce document estime les coûts[4] qu'induirait la modernisation des infrastructures de gestion des déchets plastiques pour prévenir la pollution des mers d'origine terrestre par des macroplastiques en fin de vie[5] dans les pays de l'OCDE et dans 10 pays partenaires d'Asie et d'Afrique.

Les pays examinés sont répartis dans quatre groupes en fonction de la rigueur de leur politique en matière de déchets et du niveau de développement de leurs infrastructures existantes de gestion des déchets. Les pays du groupe 1 appliquent une politique très rigoureuse et possèdent des infrastructures très développées. Ils se subdivisent entre ceux dont la politique privilégie l'économie circulaire (groupe 1a) et ceux dont l'approche reste plutôt tournée vers l'économie linéaire (groupe 1b). Les pays du groupe 2 possèdent des infrastructures moyennement développées et appliquent une politique moyennement rigoureuse, et ceux du groupe 3 se caractérisent par une rigueur faible à moyenne des politiques et des infrastructures peu développées.

Pour chaque pays, l'estimation des quantités de déchets plastiques rejetées repose sur les statistiques officielles disponibles, des publications secondaires et l'avis d'expert des auteurs. Le document montre que, dans les pays examinés, quelque 5.4 millions de tonnes de macroplastiques sont rejetés chaque année depuis la terre dans la mer en raison de la mauvaise gestion des déchets municipaux.

Deux scénarios ont été établis afin d'évaluer les investissements publics et privés nécessaires pour lutter contre les rejets de plastiques. Le scénario d'ambition modérée repose sur les solutions de l'économie linéaire, dont le renforcement de la collecte des déchets mixtes et de la mise en décharge ; il intègre également l'incinération avec ou sans valorisation énergétique et le traitement de base. Dans le scénario d'ambition élevée, il est fait appel aux solutions de l'économie circulaire, dont la prévention et des objectifs de recyclage élevés sur la base du tri des matières à la source, ce qui se traduit par une utilisation efficace des ressources et une diminution des émissions de gaz à effet de serre.

Dans les deux scénarios, on vise un taux de collecte des déchets de 100 % et un pourcentage identique de valorisation et d'élimination maîtrisées. Cela étant, les infrastructures seules ne sont probablement pas suffisantes pour ramener à zéro les rejets de plastiques dans la mer. Pour une prévention complète, il faut aussi sans doute que les comportements ainsi que les modes de production et de consommation évoluent, et que les pouvoirs publics adoptent un ensemble complexe de mesures complémentaires. Les scénarios évaluent les besoins en investissements pour tenter de remédier à la mauvaise gestion des déchets municipaux mixtes. Ils mettent l'accent sur les investissements dans la gestion des plastiques à l'extrémité de la chaîne de valeur, notamment aux stades du tri et du prétraitement. Les estimations de coûts tiennent compte de l'état actuel de l'action publique et des infrastructures en matière de déchets dans les pays étudiés.

Les coûts d'investissement sont estimés au total à 54 milliards EUR dans le scénario d'ambition modérée, et à 74 milliards EUR dans celui d'ambition élevée. Les coûts annualisés par habitant s'échelonnent entre 0.2 et 6.5 EUR dans le premier scénario, et entre 0.8 et 6.5 EUR dans le second. Dans les deux cas, ils sont bien inférieurs au coût estimé de l'inaction en cas de gestion inadaptée des déchets, qui varie en gros entre 9 et 45 USD par habitant et par an (PNUE et ISWA, 2015).

[4] Sont estimés, les coûts d'investissement et les coûts annualisés. Il ne s'agit pas d'une analyse coûts-avantages, dans la mesure où les avantages, comme les recettes tirées du recyclage dans le scénario d'ambition élevée, sont ignorés dans les modélisations.

[5] Les estimations présentées dans cette étude tiennent compte des plastiques en fin de vie. Elles ignorent ceux provenant de sources maritimes, qui sont principalement des microplastiques ou des rejets engendrés par la production (abrasion) et par la consommation (déchets sauvages).

Les calculs présentés montrent que le scénario d'ambition élevée suppose davantage d'investissements que celui d'ambition modérée : entre 6 et 26 EUR par habitant tous pays confondus, contre 0.4 à 20 EUR. Dans les deux scénarios, les coûts sont les plus faibles dans les pays du groupe 1 (politique très rigoureuse et infrastructures très développées) et culminent dans ceux du groupe 3 (politique peu rigoureuse et infrastructures peu développées).

Dans le scénario d'ambition élevée, les investissements de départ sont plus lourds, mais les coûts annualisés sont similaires dans la mesure où des économies sont réalisées[6]. En l'occurrence, les coûts annualisés dans les pays à politique rigoureuse et infrastructures développées sont similaires dans les deux scénarios : ils s'établissent à 0.2 EUR par habitant pour le groupe 1a et à 1.2 EUR par habitant pour le groupe 1b dans le scénario d'ambition modérée, et à un niveau légèrement plus élevé, respectivement à 0.8 EUR et 1.5 EUR, dans le scénario d'ambition élevée. Dans ces pays, les rejets de plastiques dans la mer sont relativement faibles, de l'ordre de 0.2 à 0.4 kg par habitant et par an selon les estimations.

Dans les pays à politique moyennement rigoureuse et infrastructures moyennement développées, les coûts annualisés sont plus faibles dans le scénario d'ambition élevée que dans le scénario d'ambition modérée (5.5 EUR contre 6.4 EUR). Dans ces pays, la production de déchets est relativement forte, les flux de déchets sont relativement riches en matières plastiques et les systèmes actuels de gestion des déchets se caractérisent par des rejets de plastiques plus élevés, estimés à environ 3 kg par habitant et par an.

Dans les pays à politique faiblement à moyennement rigoureuse et à infrastructures peu développées, il est impératif d'investir dans les infrastructures classiques de gestion des déchets municipaux mixtes. Les coûts annualisés estimés par habitant sont légèrement plus bas dans le cas du programme d'investissement plus classique fondé sur l'économie linéaire du scénario d'ambition modérée que dans le scénario d'ambition élevée : 6.46 EUR contre 6.52 EUR. Dans ces pays, la production de déchets est relativement faible, mais la proportion des déchets qui entrent dans le système de gestion des déchets l'est également. Le taux de rejet est donc plus important et se situe à 1.7 kg par habitant et par an selon les estimations.

L'actuelle pandémie de COVID-19 est à l'origine de nouveaux problèmes de gestion des déchets. Ainsi, elle a fait bondir la production et la consommation de produits liés à la santé, dont les équipements de protection individuelle et certains plastiques à usage unique (masques, gants, vêtements de protection, récipients de gel hydroalcoolique...). Le volume des déchets biomédicaux a également augmenté, accentuant les tensions dans les installations de traitement de déchets dangereux qui sont chargées de leur élimination sans danger. La pandémie a par ailleurs suscité des changements de comportement, avec notamment la diminution du temps passé à l'extérieur et du nombre de grands événements publics (qui sont généralement générateurs de déchets plastiques). Il ressort d'une étude qu'au Royaume-Uni, si chaque personne utilise un masque à usage unique par jour pendant un an, cela augmente de 66 000 tonnes le volume de déchets contaminés et de 57 000 tonnes celui des emballages plastiques (UCL Plastic Waste Innovation Hub, 2020). Cependant, l'impact global sur la production mondiale de déchets plastiques et le risque de mauvaise gestion de ces déchets sont encore flous.

[6] Les avantages, dont les recettes tirées du recyclage, sont ignorés dans l'évaluation des deux scénarios. La prise en compte des avantages dans le scénario d'ambition élevée est susceptible d'améliorer la faisabilité économique de celui-ci par rapport au scénario d'ambition modérée, mais cette évaluation n'a pas été réalisée dans le cadre de la présente étude.

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1. Introduction

Plastic pollution of the ocean has become a serious global concern; 12 megatonnes of plastic are estimated to leak into the ocean every year (Boucher and Billard, 2019[1]). Many organisations are now working to understand the scale of the problem and trying to formulate the necessary solutions for addressing it. The evidence base for making policies related to preventing plastic pollution of the ocean is increasing. However, until now, the potential costs have not been studied.

This study is a first step towards developing data and methodologies to conduct a global assessment of investment and policy incentives needed to divert land-based mismanaged plastic waste. First, it estimates leaked plastic waste quantities based on available waste statistics in selected countries, then groups countries based on analysis of the policy frameworks and infrastructure conditions in the selected countries. Finally, the main focus is on identifying the infrastructure needed and the associated costs of preventing the leaked quantities under alternative investment scenarios.

The study relies on a review of waste policies and waste infrastructure in selected countries to formulate investment scenarios that respond to the countries' needs and would theoretically prevent 100% of marine plastic pollution from end of life macroplastics. Two investment scenarios are formulated – a Moderate Ambition scenario that focuses on linear waste management solutions and a High Ambition scenario with a focus on circular economy, prevention and recycling. The associated investment and annualised costs are estimated for both scenarios.

The study estimates the costs of the needed infrastructure in the range of EUR 54 to 74 billion, depending on the level of ambition and complexity. In all country groups, capital investments per capita are higher in the High Ambition scenario, ranging from EUR 6.05 per capita in the high policy stringency and high infrastructure group to EUR 25.54 in the moderate/low policy and low infrastructure group, while in the Moderate Ambition scenario this range is between EUR 0.43 to 20.16 per capita.

The annualised costs, however, are rather similar for both scenarios in all the country groups studied. Lower annualised cost per capita occur in the moderate policy and infrastructure group in the High Ambition scenario at EUR 5.48 per capita as compared to EUR 6.36 per capita in the Moderate Ambition scenario.[7]

The remainder of this paper is structured as follows:

- Chapter 2 identifies the sources and quantity of plastic waste generation, providing a basis for the calculation of plastic leakages;
- Chapter 3 discusses the current infrastructure and policy environment to tackle plastic pollution emissions;
- Chapter 4 introduces two investment scenarios for preventing plastic leakage to the ocean, the costing methodologies and the assumptions used for costing;
- Chapter 5 presents the results, discusses their limitations and further research needs;
- Chapter 6 draws the main conclusions, the implications for the developments needed in the sector and points to the way forward to completing a global assessment on the topic.

[7] The paper estimates annualised costs. It is not a cost-benefit analysis because the benefits, including, for example, the revenues generated from recycling in the High Ambition scenario, are not included in the model. Increased revenue from increased recycling can result in benefits in both scenarios. In particular, the High Ambition scenario is likely to generate revenue in terms of resource savings and recyclables sold. However, these estimates have not been made in this study.

1.1. Geographic coverage

The geographic focus of this paper is on OECD member countries, OECD accession candidates and ten selected economies in Asia and Africa (48 countries in total) (Figure 1.1). In an effort to facilitate the analysis, countries have been grouped according to their i) level of policy stringency in the waste (and plastic waste) management sector and ii) level of waste management infrastructure in place (Table 1.1).

Figure 1.1. The 48 countries reviewed in this study

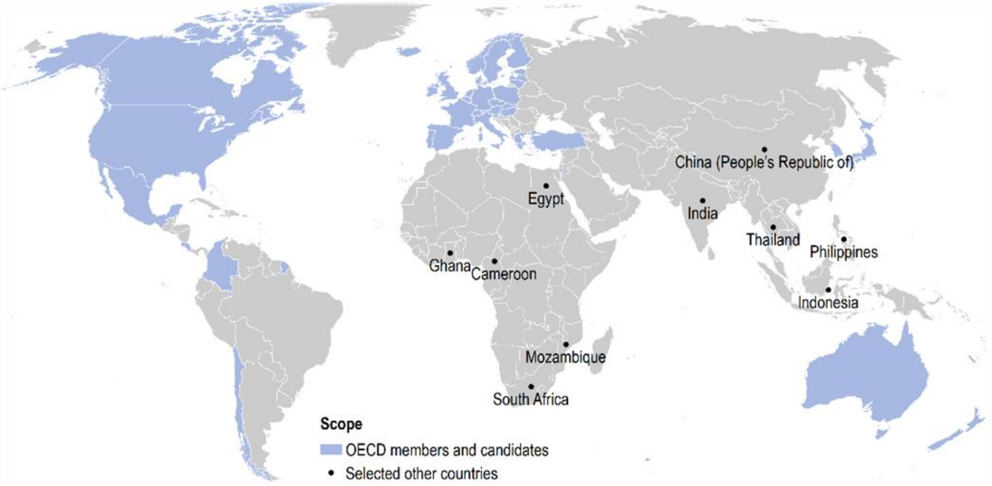


Table 1.1. Methodological parameters for grouping countries

	Group 1a	Group 1b	Group 2	Group 3
Policy stringency	High Circular	High Linear	Moderate	Moderate / Low
Infrastructure and practices	High	High	Moderate	Low
Collection rate	>95%	>90%	60-90%	<60%
Landfill dependency	<50%	<70%	>70%	>70%
Uncontrolled disposal	<1%	<1%	<50%	>50%
Recycling rate	>35%	10-35%	10-30%	<10%

1.1.1. Group 1a: High Circular Policy, High Infrastructure

In these countries, Circular Economy approaches are becoming embedded in waste and resources management legislation and practices. These countries use a combination of regulatory and economic (market-based) mechanisms to divert significant quantities of materials away from landfill. The use of these mechanisms extends into the production, supply and consumption part of the materials value chain, with the effect of placing downward pressure on the generation of waste and not only at the end point in the waste management chain (e.g. incineration or landfill). In these countries reduction, reuse and recycling (3Rs) are favoured.

1.1.2. Group 1b: High Linear Policy, High Infrastructure

In these countries, waste management policy is highly developed, but there is a relatively large reliance on Linear Economy waste management technologies, including incineration and landfilling. It is important to note that within a particular country in this group, there may be certain regions, states or provinces where there are high recycling rates and low incineration and landfill dependency; however, it is not consistent across the whole territory of the country. Within this group there is a high level of 'cradle to grave' control of the waste and materials stream; high waste collection rates and a high coverage of controlled recovery and disposal are typical.

1.1.3. Group 2: Moderate Policy, Moderate Infrastructure

These countries do not yet have a fully coordinated or implemented waste management policy, or they have such policy but the practices on the ground are not yet up to the nationally required standard. These countries do not yet have full coverage of waste collection services, and uncontrolled recovery and disposal is still prevalent. Policy instruments may be in place, but their scope may be narrow. The recycling sector may be well established; however, data are not necessarily captured in the official statistics.

1.1.4. Group 3: Moderate/Low Policy, Low Infrastructure

These countries do not yet have waste management policy in place or lack certain key elements of such policy. These countries may be lacking legislation, implementation and enforcement, finances and technical capacity. Collection services and controlled disposal may be only available in central urban areas. Recycling tends to be largely informally organised.

Table 1.2. Country groups for the purpose of this study

Group 1a	Group 1b	Group 2	Group 3
Policy stringency:			
High Circular	**High Linear**	**Moderate**	**Moderate/Low**
Infrastructure and practices:			
High	**High**	**Moderate**	**Low**
Australia	Austria	Chile	Cameroon
Belgium	Canada	Colombia	Egypt
Denmark	Finland	Costa Rica	Ghana
Czech Republic	France	Israel [8]	India
Estonia	Greece	Mexico	Indonesia
Germany	Hungary	South Africa	Mozambique
Iceland	Ireland	Thailand	Philippines
Korea	Italy	Turkey	
Luxembourg	Japan		
Netherlands	Latvia		
New Zealand	Lithuania		
Norway	Poland		
Portugal	People's Republic of China (hereafter "China")		
Spain	Slovak Republic		
Sweden	Slovenia		
United Kingdom	Switzerland		
	United States		

[8] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Countries have been allocated to the groups in Table 1.2 using the following approach[9]:

Step 1: Countries allocated according to published recycling rates of municipal waste

- Group 1a >35%
- Group 1b 25-35%
- Group 2 10-25%
- Group 3 <10%

Step 2: Countries allocated/reallocated according to municipal waste collection service coverage

- Group 1a >95%
- Group 1b >90%
- Group 2 60-90%
- Group 3 <60%

1.2. An important note before reading further

Dividing countries into groups may be controversial. The authors' intention is purely to facilitate the analysis, and not to credit or discredit one country or another. The groupings are based on a combination of published data and first-hand experience of the authors to classify countries into groupings.

Conceptualising these four country groups requires simplification. For example, there are cases where parts of a country could be classified into the 2nd or even 3rd group. Some countries exhibit differences between advanced cities and neighbouring rural hinterlands with very poor infrastructure. As such, within each group, there are distinguishable sub-groups that have not been separately identified for this study.[10]

Whilst undertaking the analysis, judgements on classifying the countries have been made with focus on plastic waste management policy and practices, and in order to reflect the general situation across the country.

[9] Countries that are allocated in Group 3 from Step 1 but rank as Group 1 from Step 2 are placed in Group 2. This adjustment reflects poor capture of recycling data in these countries.

[10] The authors have previously hypothesised nine *development bands* for municipal solid waste management policy and infrastructure (Whiteman and Soos, 2011[34]).

2. Plastic waste pollution of the ocean

Plastics are one of the world's most used materials. They are used in a multitude of ways including in single-use items, product packaging, appliances, furniture, clothes, building materials and automotive components.

The release of plastics into the ocean occurs through various pathways, including river and air transport, sewage water and storm water, beach littering, and from sea-based sources including fishing, shipping and aquaculture. Of the sources of plastic emission, land-based sources are estimated to be more significant than those generated on the sea (Boucher and Billard, 2019[1]).

Plastic waste pollution can be differentiated into (1) coastal mismanaged waste; (2) inland mismanaged waste; (3) at sea sources of waste; and (4) microplastics (Eunomia, 2016[2]) (Figure 2.1). Microplastics are of two types, (i) primary microplastics, those manufactured at micro scale to be used in particular applications, i.e. microbeads used in PCCPs[11] and plastic pellets unintentionally discharged due to accidental spills, and (ii) secondary microplastics, those stemming from the fragmentation and weathering of larger plastics (GESAMP, 2016[3]).

Figure 2.1. Diagram of plastic waste pollution of the ocean

Source: Adapted from (Eunomia, 2016[2]).

Secondary microplastics can be further categorised:

- *Use-based* secondary microplastics generated by abrasion occurring during the manufacturing and use of products containing synthetic polymers (e.g. synthetic textiles, tyres).

[11] PCCPs – Personal care and cosmetics and products.

- *Degradation-based* secondary microplastics originating from the fragmentation of larger plastic items already present in the environment.

The source of plastic emission is differentiated by whether generation occurred: a) during production of plastic, i.e. loss of materials in the production process, b) from use of products, i.e. direct release or abrasion, or c) at the end of life of a product. Macro-plastic emissions are mostly generated at the end of life of a product.

2.1. Plastic leakage into the ocean globally

Whilst there is still much to study and learn about the emission factors for release of plastics into waterways, there are several widely quoted landmark studies using different methods and focusing on different sources and types of marine litter to estimate the quantity of yearly and total plastic pollution of the ocean. Table 2.1 summarises the results of several studies, quoting the estimated amount of plastic waste generated and describing the primary focus of the research.

Table 2.1. Sources, quantities and type of plastic waste entering the ocean

Sources and type of plastic waste	Plastic waste entering the ocean
• Primary microplastics Microplastics (<5 mm) released directly into the ocean; the estimates do not include secondary microplastics that originate from degradation of large plastic waste into smaller fragments	1.5 Mt/year (Boucher and Friot, 2017[4])
• Coastal mismanaged waste All types of plastic waste generated in the world's coastal countries ending up in the ocean	4.8 to 12.7 Mt/year (Jambeck et al., 2015[5])
• Inland mismanaged waste Plastic waste generated inland and traveling to the ocean through rivers	1.15 to 2.41 Mt/y (Lebreton et al., 2017[6])
• All sources and types of plastic waste Plastic waste generated during production, consumption of products and the end-of-life of plastic	8.28 Mt/year (Ryberg, Laurent and Hauschild, 2018[7])
• All sources and types of plastic waste The estimate focuses on end-of life of plastic products that turn into waste	12.2 Mt/y (Eunomia, 2016[2])

Total plastic waste entering the ocean globally is estimated at around 12 Mt/year, the most significant portion of this is from land-based coastal plastic waste. This is equivalent to an estimated 3% of the plastic placed on the market in a given year ending up leaking into the ocean as plastic pollution (Boucher and Billard, 2019[1]).However, there are still several limitations of our current understanding of the type, source and quantities of plastic that ends up in the ocean.

Based on currently available data, we have collated a database for the 48 reviewed countries to estimate the pollution leaking into the ocean from land-based sources, focusing on macroplastics. The estimations in this study consider end-of-life plastic products. The estimations do not include at sea sources, primary microplastics, or leakage from production (abrasion) and consumption (littering).

The link between mismanaged municipal waste that ends up in the environment and subsequent pollution of the ocean is not yet comprehensively understood. Many factors influence the rate at which unmanaged plastic enters waterways, and the way these materials travel down surface water channels into major water bodies and eventually the ocean. As more surveys are conducted on land and at sea, more information on the emission factors will become available. As well, the state of knowledge is not uniform for all plastic waste streams. For example, leakage from construction and demolition waste or end-of-life vehicles is less well studied than packaging waste or single-use plastic (Ryberg, Laurent and Hauschild, 2018[7]).

2.2. Plastic leakage to the ocean from reviewed countries

Our estimations presented below include mismanaged plastic and the resulting plastic leakage from municipal waste.

Data related to waste quantities, composition, infrastructure and specific information on plastic is still relatively scarce. Whenever data is not available, assumptions are made to allow estimation of quantities of plastic leakage into the ocean as follows:

- The waste collection rate for a country is calculated as the average of rural and urban rates. Whenever the rates for a country are not available, 50% of the urban waste generation rate is taken, assuming close to no collection service in the rural area.
- Whenever the plastic recycling rate is unavailable, the recycling rate of municipal solid waste is taken as a proxy.
- Rates of uncontrolled disposal and open dumping for municipal solid waste are applied to plastic waste proportionally.

Following the most widely quoted publication on the topic (Jambeck et al., 2015[5]), data collected for the purpose of the study, and the expert judgement of the authors, the quantities of plastic waste leaked into the ocean are calculated based on the following assumptions:

- 10% of the plastic waste disposed in uncontrolled disposal sites leaks into the ocean through waterways;
- 40% of uncollected plastic waste from coastal regions and 20% from inland leak into the ocean, while the remaining 60-80% is either openly burned or goes to uncontrolled disposal sites;
- 2% of generated plastic waste is littered. This estimation is only applied to Groups 1a and 1b, countries where littering is considered to be the only source of leakage and further it is assumed that 20% of littering ends up in the ocean. It is also assumed that in countries where much of the waste is not handled and illegal or open dumping is common, littering need not be considered separately as it is already captured by the former two categories above.

Using these assumptions, the total amount of plastic leakage from municipal solid waste (MSW) and secondary microplastics for the reviewed countries is estimated at around 6.5 Mt/y, of which 1.1 Mt/y (17%) comes from microplastics and 5.4 Mt/y (83%) is due to mismanagement of municipal solid waste. The costing calculations in this study focus only on preventing mismanaged municipal solid waste (and not the microplastics for which the options are not yet well understood).

Figure 2.2. Sources of plastic leakage in the countries studied

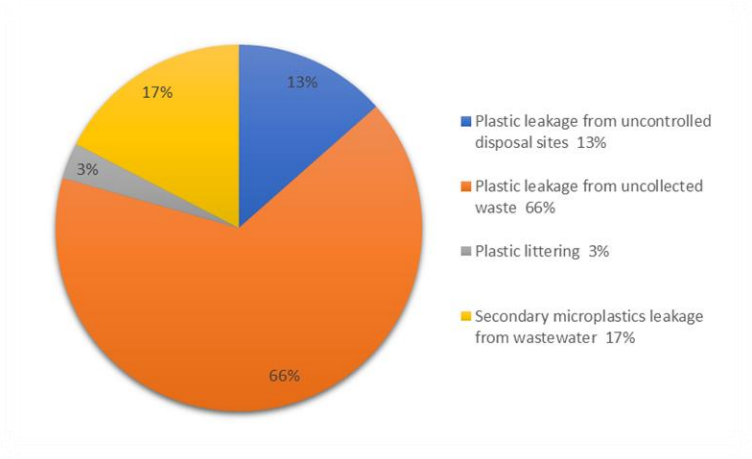


Table 2.2 shows that countries with high or moderate policy stringency (Groups 1a, 1b, 2) generate a lot of plastic waste but are able to capture and manage most of it. Countries with moderate/low policy stringency (Group 3) generate less plastic waste per capita but are emitting more to the ocean.

Table 2.2. Plastic waste generation and plastic leakage rate from mismanaged municipal waste

Country group	Plastic waste generation kg/capita/year	Plastic leakage kg/capita/year	Total plastic leakage Mt/year
Group 1a	59	0.24	0.8
Group 1b	36	0.40	1.2
Group 2	45	3.05	3.2
Group 3	9	1.71	5.4

Figure 2.3 presents the material flow and Table 2.3 the leakage estimates for Egypt, an example of a Group 3 country in the model. The rest of the studied countries are modelled in a similar way.

Figure 2.3. Baseline situation of waste management system in Egypt

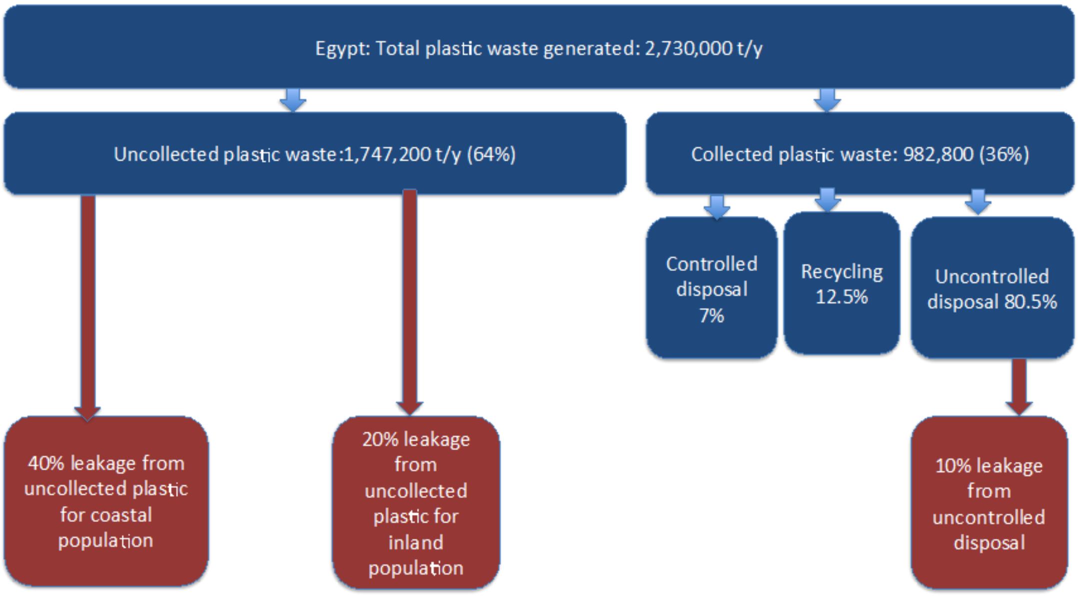


Table 2.3. Estimated plastic leakage quantities in the baseline for Egypt

Egypt baseline [t/y] (rounded)	
Municipal waste generated	21 000 000
Plastic generated	2 700 000
Uncollected plastic	1 750 000
Leakage from uncollected plastic (A+B)	430 000
A. Leakage from uncollected plastic from coastal population (40% * plastic generated per capita * population living on coast)	160 000
B. Leakage from uncollected plastic from inland population (20% * plastic generated per capita * population living inland)	270 000
Plastic in uncontrolled disposal	790 000
Plastic leakage from uncontrolled disposal (10%)	79 000
Total plastic leakage	**509 000**

3. Policies and infrastructure

3.1. Waste management policy frameworks

The level of development of waste management systems can be linked to the socio-economic development situation of the country, region and locality. Waste management is a complex public service that entails a specialised area of policy and development practice.

Waste and resource management is the business of conglomerating materials generated from disparate sources into one place for sorting and processing. Waste management is particularly challenging logistically because it involves a multitude of different stakeholders and service providers and is often required to operate without sufficient technical and financial resources.

Waste is by definition something that people do not want; and because of this, waste management services suffer from a lack of popular recognition of their utilitarian value. An enabling policy framework is necessary to improve the waste and resource management practices in a country.

A policy framework for the waste and resources management sector needs to cover a wide range of aspects:

- **Legal and regulatory framework**: how regulations are implemented and enforced, including policy instruments for circularity;
- **Institutional and organisational framework**: the interactions between multi-tier levels of government;
- **Financial framework**: how revenues are collected and channelled to pay for infrastructure and day-to-day operation of services; how economic instruments are used to incentivise circular economy;
- **Technical framework**: the availability and competency of service operators and equipment suppliers on the market;
- **Cultural framework**: the awareness and behaviour of citizens and the organisations for which they work.

Waste management can be regarded as an indicator of good governance (Whiteman, Smith and Wilson, 2001[8]). The cleanliness of a city is likely indicative of how well the government (politicians, public sector staff and contractors) are working. For waste management services to be effective, there needs to be good supervision and management, sufficient revenue provided in a timely way, good contracting and licensing procedures, and no lack of sensitivity and responsiveness to the needs and wishes of the public.

Whilst similarities can be observed in key indicators of the status of waste management between countries of a similar income level, the high importance of governance factors means that even where revenues are scarce, and where there may be a lack of technical capacity, a country or city may still be able to run a good waste management service. Conversely, high income is no guarantee of good waste management practices. Some less wealthy countries excel in waste management, while other more wealthy countries may lag behind.

The policy framework for the waste and resources management sector is quite complex, and how well it is designed, and how it functions can be easily observed by looking at the condition of the streets, open spaces and water channels.

3.2. Basic waste management services and infrastructure

Waste collection service coverage is universal in most high-income countries. People have long since become used to receiving regular and reliable services, and more elaborate separate collection services for multiple material fractions have been put in place. The established collection systems feed materials into back-end infrastructure including transfer, materials recovery, bio-waste recovery, incineration and landfilling facilities. In most cases they are developed to high environmental standards and monitored by strict regulatory requirements (Kaza et al., 2018[9]).

In contrast, middle- and lower-income countries often suffer from both a lack of service coverage and infrastructure. To a greater or lesser extent, a portion of the generated waste is not collected, and therefore either burnt in the community, or removed and dumped into the environment.[12]

Many of the world's slums and low-income settlements are located along watercourses or in low-lying areas with high water tables. In many of the world's cities, drainage and river channels are seriously polluted, further aggravating the poor living conditions.

Owing to rapid rural-urban migration, and a burgeoning urban slum population, many of the world's most rapidly developing cities have become the major hotspots for plastic pollution emissions (UN-Habitat et al., 2019[10]). Depending on the geographic location, the uncontrolled dumped plastics enter the water channels and are flushed into larger water bodies, and eventually the ocean. Coastal cities within about 30 km of a major water body are estimated to be a major source of emissions (UN-Habitat et al., 2019[10]). However, the science examining factors behind plastic transport to water bodies is far from being able to provide reliable explanations.

Waste collection coverage in central urban areas is typically good but it has deficits in other urban districts and can be very poor in densely populated peri-urban areas or slum type settlements. In rural areas, the quality of collection services is also poor or there is no coverage at all.

For the purposes of this study, the policy background and waste management practices of the countries in question have been analysed as per the four groups of countries (see Table 1.2), separated by policy environment and infrastructure types. Our analysis goes in depth into individual countries according to the information available, especially for the ten selected Asian and African economies taken as case studies.

The following sections comprise a general overview of the policy instruments and practices for plastic waste management in these countries, pointing out to specific country examples with a brief description of their experience in this regard.

3.3. Policies for plastic waste prevention, reduction, reuse and recycling

Effective policy making for plastic waste prevention, reduction, reuse and recycling requires an understanding of how waste management systems are provided, the types and quantities of plastics placed onto the market, and sensitivity to behaviour towards plastic consumption, use and disposal. As well, effective plastics waste management likely requires several actors such as a **public-private-public** partnership approach; a new tripartite relationship between the public sector, the private sector and the general public.

Waste management policy is highly location-specific with local differences in consumption and waste handling practices. The main challenges to address are: a) the type and quantities of plastics being placed and consumed on the market; and b) the relationship of responsibilities between the public-private-public triad for the end-of-life management of plastic products. Policy can play a significant role in shaping these interfaces.

The main categories of policy instruments targeted at plastic prevention, reduction, reuse and recycling include:

[12] More information can be found in the World Bank's (2018[9]) What a Waste publication, which provides aggregated data on solid waste management from around the world.

3.1.1. Bans or restrictions

Increasingly, countries are implementing total or partial bans on plastic bags (66% of 192 studied countries, as of July 2018) and other single-use plastics, such as plastic cups, plates and cutlery. Some countries (8% of 192 studied countries, as of July 2018) introduced bans or restrictions on the use of microbeads (UNEP, 2018[11]).

It is still too early to determine the impact of product bans or restrictions. In many cases, information on impact is lacking, partly because these measures were adopted only recently but also because their effectiveness is not monitored or reported. In those countries with data, about 30% register a sharp decrease in the consumption of plastic bags within the first year. The remaining 70% of countries with data report little to no change (UNEP, 2018[11]).

3.1.2. Extended producer responsibility (EPR)

Plastics are internationally traded commodities that are subject to price fluctuations. Under pure market forces, the quantities and types of post-consumer plastic that are recovered and recycled are inherently driven by the price signals from global, regional and local supply and demand. Recycling systems however involve complex collection, transport and processing, which in turn require stable revenue to operate effectively.

EPR systems create an additional revenue stream for reuse and recycling. Revenue from EPR schemes is injected in various ways, at different points in the plastics management chain in order to ensure that the costs of plastic waste management systems are recovered (OECD, 2016[12]).

There are many different forms of EPR systems because they consist of several policy tools that in their combination make producers responsible for their products at end-of-life. A binding EPR target creates opportunity costs that amount to an implicit price on some of the external environmental costs generated by plastic waste. It provides an incentive to the producers of plastic products for eco-design, light-weighting, material reduction or material substitution in products, with a view to minimising resource use and maximising recyclability.

In some countries, EPR schemes are set up and run by Governmental authorities. More often however, the role of the public sector is focused on ensuring that producers meet their obligations, ensuring a level playing field across the market. The remainder of the discussion of EPR focusses on three commonly used types of EPR.

a) Take-back systems

EPR systems commonly involve a regulated minimum recycling target, and the imposition (to a greater or lesser extent) of a responsibility to recycle on the companies who place regulated products on the market to take them back and meet these targets. Companies may meet their responsibilities independently, or through so-called “compliance schemes”.

b) Product stewardship

Product stewardship is an approach whereby the producers take voluntary initiative, i.e. without external regulatory requirements, to set and meet materials-based recycling targets.

Reporting on Corporate Social Responsibility suggests that the product stewardship model provides the maximum flexibility to firms to design and implement their own initiatives, at the pace of technological development, in accordance with the logistical realities and firm’s financing priorities.

However, the effectiveness of such voluntary actions remains to be proven as there is no standardised monitoring system to capture these experiences. The instrument carries a certain degree of greenwashing risk.

c) Deposit refund schemes (DRS)

A deposit refund scheme (DRS) is a system in which an initial payment (deposit) is made by a customer at point of purchase that is then refunded at the point that the product or packaging is physically returned by the customer to the collection scheme (OECD, 2016[12]). The direct financial reward upon return of the packaging or product means DRS are highly effective in capturing post-consumer plastic waste and materials.

DRS rely on back-end infrastructure such as collection or redemption points and counting stations. DRS has been shown as a highly effective mechanism to reduce littering and illegal dumping. DRS achieve the highest rates of material re-capture, around 90% in Europe, and even higher in other places such as South Australia.

One of the major advantages of DRS is the public awareness and behavioural change stimulus for clean separate delivery of materials to the places where the deposit can be redeemed. Other advantages include the injection of revenue to primary collectors who operate in many places of the worlds’ marine plastic emissions ‘hotspots’ and consequent reduction in littering.

Disadvantages include the cost of the ‘reverse logistics’, i.e. the systems for bringing the materials back from circulation into the production, and fraudulent deposit redemptions. DRS policy can aim to define the obligation of impacted actors, including producers, distributors/importers, retailers, consumers and the public sector (OECD, forthcoming[13]).

Pay-as-you-throw (PAYT) schemes

This economic instrument applies the “polluter pays” principle by charging citizens according to the amount of waste. PAYT is implemented in different ways depending on the data capture and accounting method in use for waste management services. The most common variants are volume-based (i.e. sack-based), weight-based and frequency-based scheme. When combined with well-developed infrastructure to collect the different waste fractions, with monitoring, as well as with a good level of citizen awareness, PAYT schemes can increase the collection and recycling rates of recyclables.

Taxes on production, distribution and consumption

Taxes can be levied on single-use plastic either at points of production, distribution or consumption, to discourage their production and use (Cornago, Börkey and Brown, 2021[14]). Such policies have not yet been commonly implemented; however, it is conceivable that their use may become more widespread in the future. Taxes on fossil fuels may have an indirect impact on plastic production from primary fossil resources, encouraging the uptake (and recycling) of the plastic materials that are already in circulation.

Waste management service charges

Charging for waste management services not only helps to cover costs, but it also acts as an incentive for waste reduction, reuse and recycling. Charging for waste management services at a level to cover the basic costs of providing household waste services, and to cover the full costs (including capital and operating costs) for the commercial and institutional waste generators is vital to ensure the constant financing of the system.

The financial sustainability of solid waste management systems is one of the greatest challenges in the latter two groups of countries (Group 2: Moderate Policy, Moderate Infrastructure; Group 3: Moderate/Low Policy, Low Infrastructure). Charge collection systems for solid waste management services are not always in place and, where they are, the levels of charging are either too low or the mechanism for charging is not yet effective. As a result, the total waste management costs (including capital as well as operating costs) are rarely covered by service charges collected from waste generators.

The policy instruments listed above encompass a wide diversity of specific types of mechanisms for plastic capture. Each type of policy measure is directed at a certain target material and stage of production, consumption or disposal. Each has the potential to re-orient plastic use and improve waste management practices, but the level of effectiveness depends on how they are implemented and in what mix of instruments.

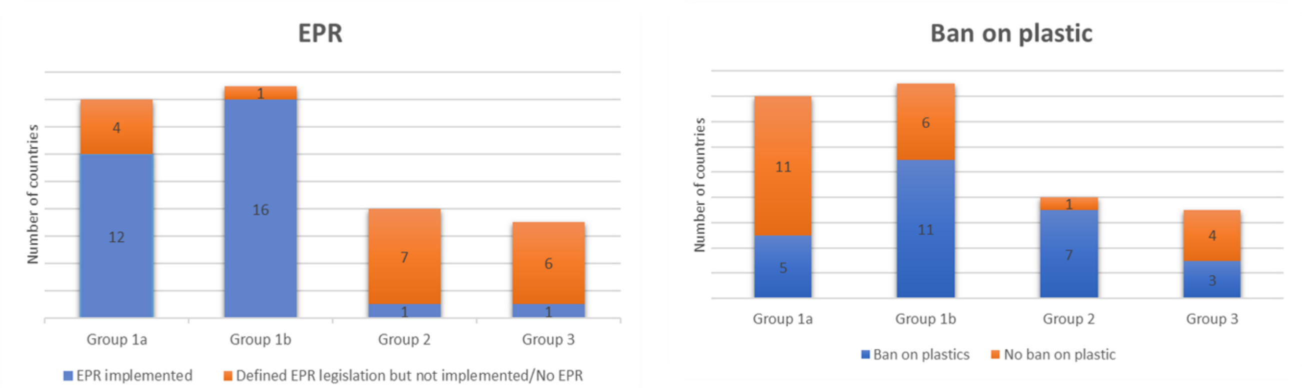
An integrated plastic waste management policy requires a combination of measures, and there is not necessarily a right or wrong approach. A balanced set of policy measures containing a combination of regulatory and economic (market-based) instruments could efficiently reduce plastic emissions.

The choice of an appropriate waste management policy can depend on the recyclability and value of plastic waste stream. For example, for plastic waste that is easy to recycle and control and has high material value, EPR systems may be the most efficient. For other materials that are difficult to recycle and collect, like some of the single-use plastic waste streams, a ban may be the best option. At the same time, other instruments such as PAYT could incentivise a different consumption pattern altogether and a shift to more sustainable products. Therefore, a combination of these instruments is needed to suit the material flows and the local context to efficiently reduce plastic emissions. Whatever policy package is adopted, it is preferable for decisions to be based on a detailed assessment of the options, their strengths and weaknesses, opportunities and threats, alongside calculation of costs, benefits and wider economic impacts.

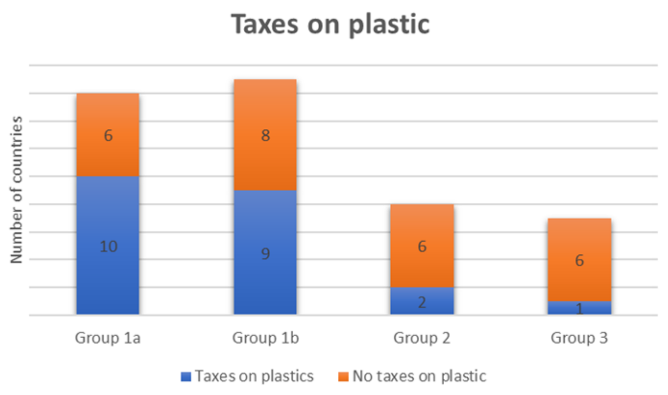
3.4. Current policy context and management of plastic waste

A range of plastic-related policies, regulations and practices have been introduced and implemented in our sample countries (Figure 3.1). Approaches to plastic waste management vary from group to group and country to country, depending on the overall resource and waste management policy framework.[13]

Figure 3.1. Brief overview of the policy responses in the studied countries



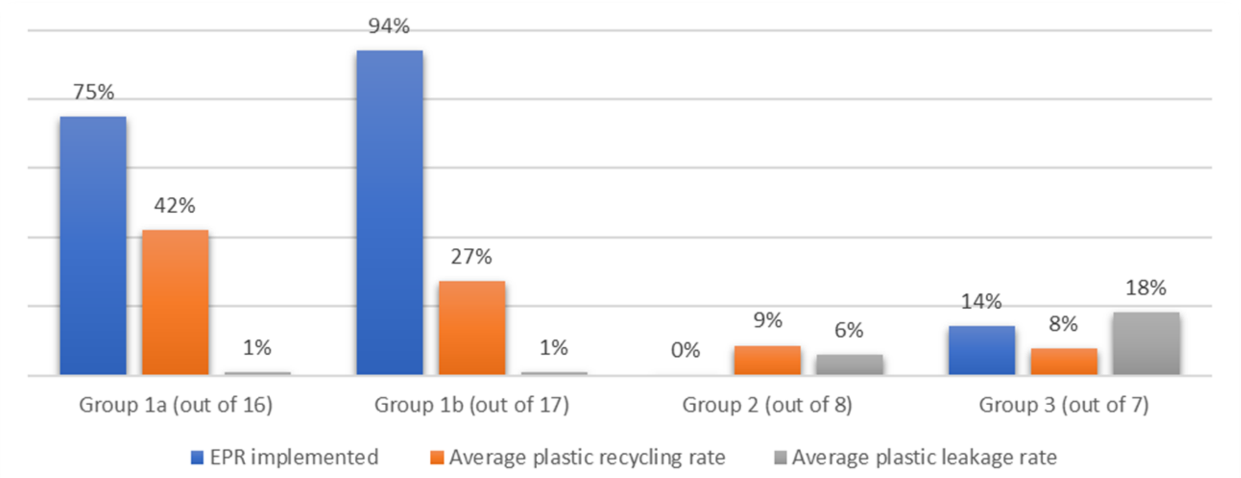
[13] See the OECD Policy Instruments for the Environment (PINE) database for detailed country data on taxes, charges, DRS and subsidy schemes related to waste management (http://oe.cd/pine).



Source: Author's (RWA Group) own.

We find that countries with a combination of plastic-related policies and regulations achieve recycling rates at around or above 30%. These countries tend to have EPR systems in place together with bans on certain plastic items. Conversely, most countries without EPR systems tend to have recycling rates below 20%, even in the presence of bans (Figure 3.2).

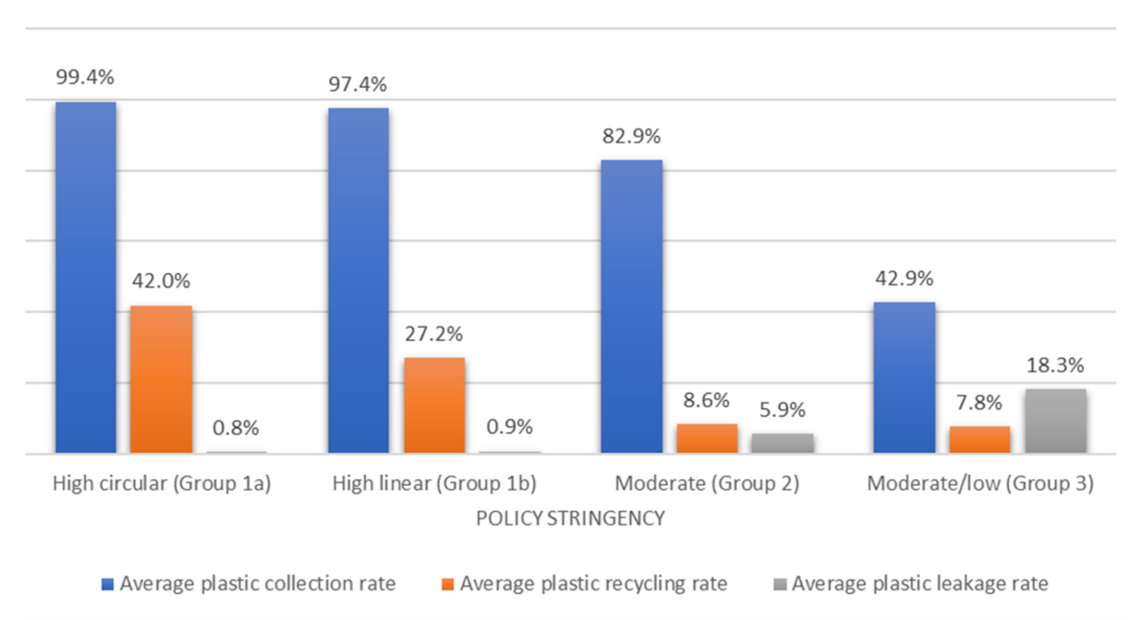
Figure 3.2. EPR implementation correlates with higher plastic recycling and lower plastic leakage rates



Source: Author's (RWA Group) own

There is a clear relationship between the stringency of waste policy (regulatory and market-based instruments) and the plastic waste management performance of the studied countries. Though a variety of factors may be at play, introduction and implementation of EPR is linked to reduced leakage while enhancing the collection rates and boosting the recycling sector, especially in countries with high waste policy stringency (Groups 1a and 1b) (Figure 3.3). These data suggest that countries with suitable enabling policy frameworks for plastic waste management can achieve high collection and recycling rates and low plastic leakage rates.

Figure 3.3. More broadly, policy stringency correlates with higher plastic collection and recycling and lower plastic leakage rates



Source: Author's (RWA Group) own.

3.4.1 High policy stringency countries – Groups 1a and 1b

This group of countries consists of the most industrialised economies with a comprehensive policy framework and infrastructure for waste management. Within this broad category of countries, the specific approach to plastic management varies widely; however, regardless of the final destination (e.g. recycling, incineration or landfill), the management systems in place consistently capture plastic materials.

The countries in this category include most (32) OECD members and China (see Table 1.2 in the Introduction). As this is a large group of countries with a broad diversity of waste and resource management policies and infrastructure types, we have further sub-divided this category into two: Group 1a) countries reporting >35% recycling and Group 1b) countries reporting <35% recycling.[14]

Across the EU member states and in certain locations within the countries in this group, EPR systems are in place to organise and finance packaging recycling systems. Financing generally comes from suppliers – producers and retailers – or is raised from consumers via product taxes. This allows externalities relating to end-of-life management to be reflected in product pricing (D'Ambrières, 2019[15]).

These countries often use economic instruments to increase the cost of incineration and landfill in order to stimulate the diversion of materials towards recycling. Countries in this category typically attain recycling rates above 30%.

[14] This categorisation may not reflect actual differences in recycling rates as data are reported differently across countries. In some countries it may be at the beginning of the value chain (whatever is source separated) in other countries it is at the end of the value chain (whatever is processed). Also, it may include or exclude some materials from the national definition. Yet in other countries composting is classified as recycling.

Data sources used: OECD (2019); World Bank (2018); Eurostat (2017/2018); UNEP and ISWA (2016[21]); and other studies and reports indicated in the list of references.

The EU Circular Economy Package, adopted in May 2018, includes stringent requirements and new rules which seek to create major structural changes for plastic production, consumption and waste management practices. The aim of the new rules is to help prevent waste, and where this is not possible, significantly step up recycling of municipal and packaging waste. They plan to phase out landfilling (with a target of 10% or less by 2035) and promote greater consistency in the use of economic instruments, such as EPR, PAYT, and DRS across the European Union (EU).

The new EU waste policy aims to strengthen the "waste hierarchy", requiring EU member states to take specific measures to prioritize prevention, re-use and recycling above landfilling and incineration, thus promoting the circular economy model. Table 3.1 summarises the common EU recycling targets.

Table 3.1. The EU recycling targets

	by 2025	by 2030
Recycling targets for packaging	65%	70%
Recycling targets for plastic	50%	55%

Source: (European Commission, n.d.[16]).

Many EU and non-EU OECD countries apply PAYT systems, which is another instrument type that can help drive up recycling rates. PAYT is one of the contributing factors for successful separate collection of waste fractions. Differences can be observed in the design of PAYT systems between several EU Member Countries, including **Austria**, **Germany**, **Finland**, **Ireland** (these countries use PAYT schemes most intensely), **Luxembourg,** and, to some extent, **Netherlands**, **Denmark** and **Sweden**. PAYT systems based on volume of container and frequency of collection is the most common approach. In general, it appears that relatively few municipalities use weight as the basis for the PAYT fee.

Slovenia uses PAYT schemes, whereas **Lithuania** has adopted regulations and measures to support the system but they have not been implemented in practice. Countries sometimes face legislative obstacles in implementing the PAYT schemes. For example, the fees in **Greece** are determined based on the size of the property, not the amount of waste produced. In the **Slovak Republic**, one of the challenges for the implementation of PAYT is the lack of enforcement of payment of fees (DG Environment and European Commission, 2019[17]).

In 1995, **Korea** launched a volume-based waste fee system which applies to the collection of municipal solid waste. According to Seoul's statistics, the volume of waste generated has reduced by 8% in 1995 and 11% in 1996. Since the volume-based waste fee system has been instituted, consumers have changed their pattern of waste generation and improved awareness of waste disposal. Since 2013, the Seoul Metropolitan Government instituted the same system for food waste. Considering the relatively heavier weight of food waste, the government has recommended that authorities adopt weight-based waste fee system instead of a volume-based system. The weight-based system has reportedly reduced the food waste by 10 to 30% (Shin Lee and Yoo Gyeoung Hur, 2015[18]).

In most **OECD countries** fixed monthly or quarterly charges (otherwise also known as flat charges) are the most common instrument, defined in terms of the number of persons in household. However, some cities apply a combination of flat charge and variable charge (PAYT), which means a fixed price per household or bin combined with additional variable fee considering bin size and/or collection frequency. Although the effectiveness of PAYT schemes varies, there is a correlation between the type of charge applied and the collection rate. Implementation of PAYT for MSW collection within the fee system is one of the main factors for successful separate collection of waste fractions, which in turn stimulates the recycling activity. The best performing EU capital cities have a PAYT system in place that is based on residual waste, and which cross-finances the collection of other separately collected fractions. Cities that apply PAYT systems exhibit a higher ratio of weight of separate collection to MSW generation compared to cities with a flat rate (Table 3.2).

Table 3.2. Cities with differentiated charging schemes achieve the highest waste collection rates of source-separated recyclables

	PAYT	Flat rate + PAYT	Flat rate	n/a
	Berlin, Budapest, Dublin, Helsinki, Ljubljana, Tallinn, Vienna	Copenhagen, Stockholm, Warsaw	Amsterdam, Brussels, Lisbon, London, Luxembourg, Paris, Vilnius	Athens, Bratislava, Madrid, Prague, Riga, Rome
Average collection rate (source-separated and separately collected MSW / generated MSW quantities)	35%	17%	17%	10%

Note: n/a = data not available
Source: BiPRO/CRI (2015).

The EU countries often choose economic instruments (EPR, PAYT) as well as other measures ranging from bans (Italy, France) to agreements with the private sector (Austria). The current European Commission's "European Strategy for Plastics in a Circular Economy" (2018-2030) adopted in January 2018 aims to reduce the unnecessary generation of single-use plastic waste and eliminate over-packaging.

In **Australia**, the framework conditions for waste and resource management vary by State. South Australia has the highest recycling rates, due to a combination of mechanisms to stimulate diversion from landfill. These include an influential 'change agent' State organisation specialised in the sector, a well-established deposit refund scheme (in place since 1974) and a high landfill levy. Other States adopt different policy mixes which stimulate different types of infrastructure. Whilst some Australian States are very actively pursuing circular economy policies, this is not the case across the whole country.

In **New Zealand**, given the considerable public pressure from various groups to act on single-use plastic bags and considering the lengthy process needed for a law to be enacted, the Ministry of Environment decided to pursue a voluntary agreement with actors in the private sector. In 2017 officials engaged with the two largest supermarket chains to encourage them to either charge for or voluntarily ban single-use carrier bags. Both chains announced the complete phase-out of such bags by the end of 2018 (UNEP, 2018[19]).

Japan is the second largest per capita producer of plastic waste in the world after the United States, and while it has a comparatively high recycling rate, it has not yet introduced government policies to reduce consumption of single-use plastics. Plastic bag consumption is instead being reduced through partnerships – agreements and voluntary actions by citizens, businesses and government. For instance, industries including supermarkets, laundry services, pharmacies and DIY stores charge for plastic bags and as a result 95% of consumers bring their own bags.

Korea has a well-developed and fully-fledged policy framework using a mix of instruments associated with quantitative targets for waste reduction and recycling. Priority is given to the economic value of waste as a resource. The country employs a range of complementary policy instruments to encourage waste reduction, reuse and recycling. These include separate collection requirements, mandatory recycling targets for packaging materials and products, voluntary agreements for waste reduction and recycling in businesses, a landfill ban on food waste, economic instruments such as volume-based municipal charging schemes and DRS for beverage containers, EPR and take-back systems for waste that is easy to recycle, and charging schemes for business waste and for products that are difficult to recycle or contain harmful substances (OECD, 2017[20]).

Recent data from **China** demonstrate the enormous step forward that has been made in development of urban waste management systems over the last decade. The models being used globally to estimate plastic emissions from land-based sources are based on 2010 data. These are now quite outdated and do not adequately capture the policy efforts that China has made, and the massive infrastructure development that has taken place. Most

Chinese cities have universal waste collection coverage and apply international standards for incinerators and landfill sites. Further diversification of waste recovery and disposal solutions as well as permanent updating of the data on recycling are lacking, but efforts are being targeted on this.

The sector partially operates informally and falls under control of different national Ministries. China is now rolling out a system of separate MSW collection and it is overhauling its recycling industry, with a view to meeting a nationally set 35% recycling target. Application of an EPR mechanism, and DRS is being considered. Accompanying these efforts, China has introduced strict quality controls on the import of recyclables and is currently working on a comprehensive policy programme aimed at plastic pollution prevention (including bans and restrictions on single-use plastic items).

3.4.2. Moderate policy stringency countries – Group 2

This group of countries is characterised by a moderate level of the policy framework and infrastructure development. The focus is on traditional waste management methods with a dependency on landfill. There are few regulatory and market-based mechanisms in place to stimulate the recycling industry. Countries in this category typically attain recycling rates around 20%.

Even though the EPR system is almost non-existent in this group of countries, **South Africa** has accumulated considerable experience with EPR, both voluntary and mandatory, with different degrees of success. Voluntary programmes have been more successful than mandatory ones. A mandatory EPR programme for plastic bags failed probably because of the low recycling potential and low market value of plastic bags. In the case of PET packaging, voluntary EPR programmes were undertaken by the relevant industries while still involving government (UN Environment, 2016[21]). South Africa introduced a ban on plastic bags and imposed a levy to be paid by customers at the point of sale. It recorded a brief success in reducing plastic litter due to the fact that users became used to paying the fee.

In **Chile**, EPR became a topic of policy focus when the country joined the OECD. A 2016 law seeks to promote recycling and EPR schemes, notably for six priority products: lubricating oils, electrical and electronic equipment, batteries, accumulators, packaging and tyres. Moreover, the law also considers the inclusion of the informal recycling sector, mainly waste pickers, as accredited waste operators, once they obtain the corresponding certification. Regulations for tyres have already been adopted and will enter into force in January 2021 and regulations for lubricant oils are under development. On 16 March 2021, Chile published its EPR law for packaging. The processes for the other products (WEEE, batteries) should start and be completed by the end of 2022. Chile has also adopted several instruments related to plastics, including a ban on delivery bags from retailers (2018), rules and conditions for the treatment and final disposal of aquaculture waste (2021), a ban on the delivery of plastic products in food establishments and regulation for the composition of plastic bottles to improve their returnability (2021). Non-binding policy initiatives concerning plastics include the Roadmap for a Circular Chile in 2024 that sets a recyclability goal of 65% for MSW by 2040, the Chilean Plastic Pact as a public private partnership to rethink the future of plastics design, and the National Strategy for Marine Waste and Microplastics Management that sets an objective for reducing the discharge of plastic waste into ecosystems and reducing environmental impacts of plastics throughout the lifecycle.

Turkey began its Zero Waste Project in 2017 and has amended several environmental laws to expand upon its EPR system with, for example, a compulsory deposit refund scheme for packaging and charges for plastic bags. As well, the definition of the recovery contribution share, scope of covered products, and a fee schedule has been added to existing law. The policies seek to both spur reductions in waste generation and to provide financial resources for the further development of the country's waste management infrastructure. While there is currently extensive use of landfills, great strides have been made in extending waste collection services and increasing recovery rates. As of 2018, 1 395 of 1 399 municipalities have provision of waste services (Türkiye İstatistik Kurumu, 2019[22]). Turkey reported recovering 22.4% of waste at the end of 2020 and aims to increase its recovery rate to 35% by 2023. If current trends in municipal waste management and recovery rates continue, Turkey will soon be comparable to the high policy stringency countries in group 1 of this report.

In 2017, the Government of **Costa Rica** announced a national strategy to phase out all forms of single-use plastics by 2021 and replace them with alternatives that biodegrade within six months. The aim of the ban is to eliminate not only plastic bags and bottles but also other items such as plastic cutlery, straws, containers and coffee stirrers.

Southeast Asian countries have a diverse level of policy frameworks. Similarities in population size and density provide opportunities for economies of scale in waste management. Informal recycling sector is quite prevalent across Asian waste management systems. The extent of plastic materials capture, management and recycling varies widely, depending on a multitude of factors. Waste collection services are not yet universally provided, and a large proportion of waste is being sent to uncontrolled disposal sites.

In June 2017, **Thailand** pledged to reduce plastic use. A ban on single-use plastic bags at major stores was enacted to take effect on 1 January 2020, continuing a campaign launched by the government and retailers towards a complete ban in 2021 to reduce waste leakage to the sea. The Ministry of Natural Resources and Environment stated that the country reduced the use of plastic bags by 2 billion (5 765 tonnes) in 2018, within the first phase of a campaign to encourage consumers' voluntarily refusal of plastic bags from stores. The Plastic Waste Management Road Map for 2018-2030 also includes an ambitious plan for Thailand to use 100% recycled plastic by 2027 in various forms, including turning waste into energy (Vassanadumrongdee and Marks, 2020[23]; Chankaew, 2020[24]). In **India,** several states and cities have introduced bans on plastic carrier bags of a certain size and thickness and other plastic materials (UNEP, 2018[19]).

Across Asia, several countries have tried to control the production and use of plastic bags through levies. Still, the enforcement of regulations has often been fragmented, and single-use plastic bags continue to be widely used despite prohibitions and levies.

3.4.3. Moderate/low waste policy stringency countries – Group 3

In this group of countries, the focus is on traditional waste management methods with a high dependency on landfill. There are few policy mechanisms in place to stimulate the recycling industry, and recycling rates of less than 10% are reported.

Strong incentives provided by economic instruments have been introduced in parts of the **Philippines**, where the target of 25% waste diversion from landfill has led several local authorities to institute a PAYT system. In the city of Bayawan, this has resulted in a 20% reduction of waste sent to landfill. Households give or sell their recyclables directly to waste collectors.

Indonesia has set ambitious targets for developing waste management infrastructure and tackling plastic pollution, including a target for reducing the leakage of plastic pollution to the ocean by 70% by 2025. Social movements have emerged targeting a reduction in plastics use, and although these have been backed up by the national government strategy towards 2025, and with a waste management law focusing on waste segregation, EPR, etc., implementation is lagging behind policy ambition. Indonesia is a highly decentralised country in policy terms; some of the regional and local governments have demonstrated their commitment to tackling this issue through local laws banning single-use plastics. However, these initiatives have not yet been adopted and applied at the national level. There is still no implementing regulation (in the form of incentives or sanctions) for the EPR mechanism (Rasyadi, 2019[25]). Plastic waste imports rose sharply from 10 000 tonnes/month in 2017 to 35 000 tonnes/month in 2018. Most of the imported waste is in poor condition and not suitable for recycling.

In **Egypt**, several initiatives have been introduced by the civil society to tackle plastic pollution. For instance, the Egypt Ban Plastic coalition (2019) supports the ban on single-use plastic bags and raises awareness**.** No measures have yet been adopted nationally; however, the Egyptian Ministry of Environment has established a central Waste Management Regulatory Agency (WMRA).

In **Cameroon,** there is a ban on the use and commercialisation of plastic bags, issued by a joint ministerial order signed in 2012 between the Ministry of Environment, Nature Protection and Sustainable Development and the Ministry of Trade. The SDG Target 14.1 on reduction of marine pollution has inspired the re-examination of single-use plastics in Cameroon. Many challenges exist related to waste collection and disposal, enforcement of regulations, stakeholder involvement and awareness. For instance, there is no public information on the need to separate plastic bottles from other waste materials (Tabeyang, 2018[26]).

In **Ghana**, the Ministry of Environment, Science and Technology considered taxation as the most effective policy instrument to change the behaviour of consumers and producers on plastic consumption and production. Regarding a plastic ban, the Ministry foresaw enforcement challenges due to general enforcement issues of strict policies in Ghana. In contrast, a tax could be easily integrated into the existing tax regime, making administration and enforcement more reliable and cheaper. There is no timetable yet in place for introduction of an EPR system on packaging (Netherlands Enterprise Agency, 2019[27]).

PAYT charges have been very rarely implemented in this group of countries because the systems for constantly measuring household waste production (through standard containers or weighing systems) are not widely established and are considered to be too costly. However, in **Mozambique** (Maputo city, for instance), there is a waste user charge for residential service users, which is linked to the electricity bill that was introduced in 2007.

In many Asian and African countries, with the notable exception of waste charges and fees, –there is a lack of knowledge on implementation schemes for economic instruments. It is often assumed that their application is too complicated or costly, and therefore, voluntary agreements with the private sector are more common.

4. Investment strategies and cost assessment methods

4.1. Investment strategies

In this paper, two scenarios reflecting different levels of ambition are constructed: 1) Moderate Ambition scenario and 2) High Ambition scenario. In each scenario, an assessment of the funds needed to deal with the plastic leakage, and the sensitivity of costs to an increased level of circularity and recycling is estimated.

The scenarios take into consideration the need for public as well as private sector investment. Investments under EPR infrastructure, for example, are mainly from the private sector. To achieve comparable results across the studied countries, the analysis in this paper includes all sources of investment.

Both investment strategies target 100% waste collection rate and 100% rate of controlled recovery and disposal. For context, uncollected waste and uncontrolled management of waste are estimated to cause 83% of the total plastic leakage globally (Boucher and Billard, 2019[1]).

In both scenarios, Asian countries dominate in terms of future infrastructure capacity needs due to their large populations and high per-capita leakage rates.

Scenario 1 "Moderate Ambition" is a comprehensive scenario with mainly linear economy solutions. It assumes that most of plastic leakage is most cost-effectively addressed by:

- 100% collection coverage with mixed waste collection to eliminate plastic leakage from uncollected waste; and
- 100% controlled recovery and disposal by constructing or upgrading disposal sites to eliminate leakage from uncontrolled disposal.

Some investment in energy recovery facilities is included in this scenario. It is assumed that energy recovery eases pressure to cope with large waste tonnages and the costs of pre-treatment and transport from mega cities.

Table 4.1 shows the capacities needed under the Moderate Ambition scenario, using the example of Egypt (a Group 3 country).

Table 4.1. Infrastructure capacity needs in Egypt in scenario 1 "Moderate Ambition"

Egypt Moderate Ambition scenario capacity needs (1000 t/y)	
Mixed waste collection (uncollected waste)	13 440
Recovery	-
Landfilling (uncollected waste + waste disposed to uncontrolled sites or open dumps)	19 500

Table 4.2 presents estimated capacity needs for the four country groups studied.

Table 4.2. Estimated capacity needs in scenario 1 "Moderate Ambition"

Infrastructure	Group 1a	Group 1b	Group 2	Group 3
Estimated capacity needs (1000 t/year)				
Mixed waste collection	800	16 100	26 500	164 700
Energy recovery facilities	-	5 100	1 100	14 500
Landfilling	800	28 000	60 000	212 600

This scenario is already supported by the policies of many countries, as collecting waste is a public health priority and constructing controlled landfills is generally considered an environmental protection priority. Full collection coverage and controlled landfills are basic minimum requirements for waste management, regardless of the recovery infrastructure in place.

The scenario works under the assumption that countries need to first tackle the most basic needs in the simplest way possible while policies and further measures can be added later once the most urgent problems are dealt with. Group 1a countries typically already have sufficient recovery facilities in place to achieve the goals of this scenario. A limitation of this scenario is that Group 1a and 1b countries, and some Group 2 and 3 countries, have already stated their ambition to move beyond a linear economy approach, more in line with the goals of the second scenario.

Scenario 2 "High Ambition" is an ambitious scenario that seeks circular economy solutions. These extend into the policy realm of waste prevention, reduction, reuse and recycling and waste management solutions across the entire service and value chain.

This scenario seeks recovery options higher up in the recycling chain, first looking at prevention and circular economy. These measures are estimated to reduce plastic in the waste streams by 5 to 10% depending on the intensity of investment in Group 1b, 2 and 3 countries, and by 15% in Group 1a countries who are the assumed forerunners of circularity in the scenario. The waste generated is directed either to mixed collection or source-separated collection systems, prioritising sorting and recycling as solutions. In some countries, 100% of materials are directed to the source-separated route, destined for differentiated back-end recovery infrastructure, while in others separate collection, sorting and recycling is assumed to be 50% of the materials generated. This depends on the specific waste infrastructure and policy stringency of the given country modelled.

Depending on the country, even after mixed collection, materials can be redirected to recovery facilities, such as mechanical biological treatment (MBT), refuse derived fuel (RDF) production, and incineration with energy recovery. In China, for example, 50% of the materials collected in the mixed collection system are directed to incineration with energy recovery; these assumptions are based on the policy and technical development of the country. By contrast, in India waste collected in the formal collection system is mostly directed towards landfill, whereas the informal sector operates in parallel to extract the materials of recyclable value. In each process, step waste residues are assumed at 10% and are directed to landfill.

The calculations based on these complex scenarios result in estimated capacity needs for each process step. Figure 4.1 presents a detailed example for Egypt (a Group 3 country). Before the waste management process starts, the circular economy solutions have a prevention impact that lowers the generated waste quantity and therefore also lowers proportionally the uncollected waste. The process flow diagram shows that for mixed waste recovery, all uncollected waste quantities are considered when calculating capacities, while for source separated collection only dry waste is considered and then for reprocessing capacities only plastic waste content of the dry waste. As such, certain infrastructure elements that are important for waste and resource management as a whole fall out of the calculations as the focus of the study is on plastic waste and materials.

Figure 4.1. Calculation of infrastructure capacity needs in Egypt in scenario 2 “High Ambition”

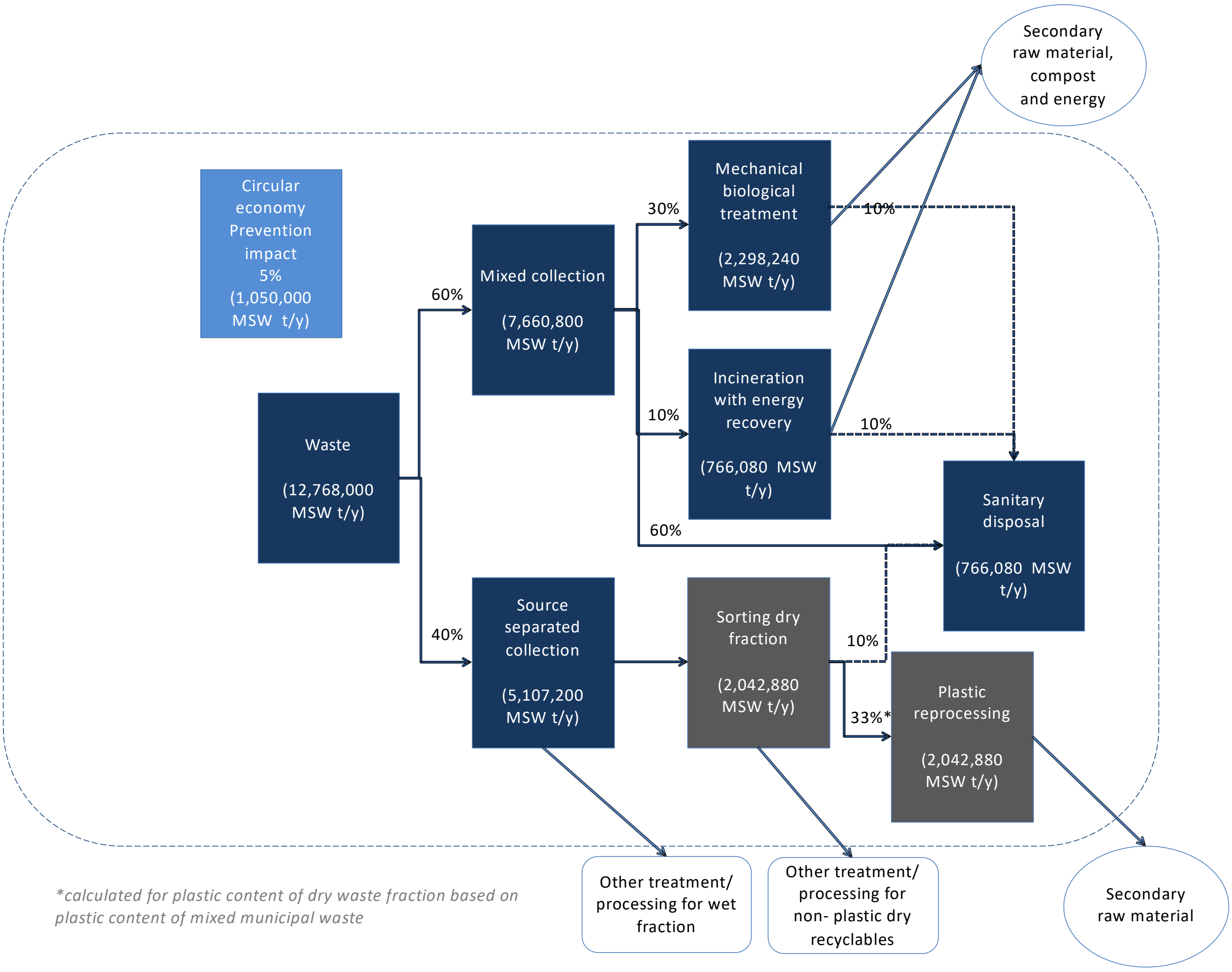


Table 4.3 presents a summary of infrastructure capacity needs for the four groups of countries. Comparing the two scenarios, capacities needed for landfilling, a linear economy solution, significantly decrease once waste generation is prevented and waste is diverted to different recovery and recycling facilities.

Table 4.3. Estimated capacity needs in scenario 2 “High Ambition”

	Group 1a	Group 1b	Group 2	Group 3
Estimated prevention impact of circular economy initiatives (1000 t/year)				
Circular economy strategies including closed loop recycling and community-based initiatives	26 400	58 100	13 900	8 100
Estimated capacity needs for waste management (1000 t/year)				
Mixed waste collection	-	3 700	100 200	12 500
MBT with RDF production	-	-	16 400	6 300
Source separated collection	700	11 200	56 300	12 600
Sorting (clean MRF)	300	5 600	22 300	5 100
Plastic reprocessing	100	1 200	3 600	1 400
Incineration with energy recovery	-	1 800	16 400	1 700
Landfilling	-	4 500	65 900	10 000

Note: MBT = mechanical biological treatment; RDF = refuse derived fuel; MRF = material recovery facility.

The High Ambition scenario would require a comprehensive set of policies to achieve the desired state and to meet assumptions used to generate the estimate. As discussed in Chapter 3, the most advanced policies are the basis for the highest recycling rates and lowest plastic leakage rates.

4.2. Costing waste management solutions

Cost estimates for linear waste management systems are based on decades of experience in waste management infrastructure investments and delivery of services. At a strategic level of costing, benchmark costs are commonly used to estimate investment. Cost estimations used here reflect the costs of the entire waste stream when looking at collection, recovery and landfilling. Only the dry waste fraction is considered when costing sorting facilities for mixed dry recyclables, and only the plastic waste quantities are considered for plastic waste pre-processing installations. Cost estimates include consideration of litter clean-up, waste collection, mixed waste recovery, recycling, and landfilling, and the costs are annualised (to account for inflation and discount rates).

4.2.1. Litter clean-up costs

Clean-up costs are defined as public provision of clean-up actions. Cost estimates are based on a recent comprehensive study by Deloitte that models and estimates clean-up implemented by government based on budget figures. Coastline, waterways, marinas and ports are considered in the study (Viool et al., 2019[28]).

Table 4.4. Benchmark costs for litter clean-up

Waste management solution	Range of benchmark cost [EUR/capita/year]
Clean-up cost	0.05 - 0.26

Source: (Viool et al., 2019[28]).

Clean-up is an ongoing activity with ongoing costs. However, it is assumed that the costs will be significantly reduced or eliminated once infrastructure is in place to properly manage or to implement circular economy solutions. Thus, costs are estimated and used in the discussion section of this paper in order to illustrate the costs avoided once either of the proposed investment scenarios are implemented.

4.2.2. Waste collection costs

Unless waste and materials are collected, plastic leakage cannot be controlled and downstream recovery and disposal cannot be guaranteed. The costs of collection systems vary and depend on many factors, including the type of equipment, the number of fractions separated at source, the frequency of the service, the density of population, and the distance to the treatment or disposal site.

For the purposes of this study, mixed waste collection costs are estimated based on specific capital costs taken from the Global Waste Management Outlook, ranging from EUR 63 to 90 per tonne (UN Environment, 2016[21]). Costs related to collection of source-separated waste are higher than this. Costs for separate collection are based on a study commissioned by DG Environment on Costs for Municipal Waste Management in the EU (DG Environment and European Commission, 2012[29]). The specific total cost reported in this report for packaging waste separately collected ranges from EUR 100 to 575 per tonne. These costs are full costs, including maintenance. The DG study does not estimate benchmarks for capital costs for source-separated waste collection, therefore this study assumes these are 20% higher than mixed waste collection, respectively EUR 76 to 108 per tonne.

4.2.3. Mixed waste recovery costs

Benchmark capital costs of mechanical biological treatment (MBT) and incineration with energy recovery are included in these process steps. Costs for these recovery processes vary depending on the technology, the feedstock composition, calorific value and the output of the technology. For example, mechanical biological treatment (MBT) may produce refuse-derived fuel (RDF) from mixed waste or low-grade recyclables, depending on the market for outputs. Incineration with energy recovery may be a co-incineration in an industry or existing power plant, or a stand-alone incinerator using different types of technologies. The costing methodology in this paper takes into account costs of treating the mixed waste streams as these technologies treat plastic as part of the waste stream.

4.2.4. Recycling costs

Benchmark capital cost of sorting facilities for clean, separately collected recyclables and plastic recycling facilities are included in the recycling chain. Costing takes into account the dry recyclable fraction of the waste for each country for sorting stations and the sorted plastic materials for the recycling facility. Case studies show a range of costs between EUR 250 to 750 per tonne for these types of facilities (Bio by Deloitte, 2019[30]). Following the modelling input in the recent investment cost demand study commissioned the DG Environment, this study assumes EUR 700 per tonne.

4.2.5. Landfilling costs

Landfilling in controlled facilities is a widely-used, affordable waste management technology. The capital cost of landfilling is strongly country-specific as it includes the cost of land, civil works, synthetic liners, weighbridges, leachate treatment equipment, landfill gas management equipment and heavy machinery for operation (including bulldozers, excavators and compactors). The cost depends on many factors, including whether the equipment is locally manufactured or imported.

The per unit investment cost is highly sensitive to the specific capacity of a landfill. Even a small landfill needs equipment for levelling and compacting the emplaced waste, some form of leachate capture and treatment and landfill gas collection. The higher the quantities, the lower the specific unit costs for these fixed elements (increasing returns of scale). Therefore, the range of costs in this category is rather large in this paper. The costs are calculated for 10 years of landfilling capacity.

Table 4.5. Summary of benchmark capital costs used in this paper

Waste management solution	Range of benchmark cost [EUR/t]
Mixed waste collection and transfer	63-90
Collection of source separated waste and transfer	76-108
Sorting station for clean recyclables	142
Plastic recycling facility	700
Mechanical biological treatment for mixed waste	339
Incineration with energy recovery	791
Landfilling	82-102

Source*:* Based on (UN Environment, 2016[21]), (Bio by Deloitte, 2019[30]) and author's (RWA Group's) own calculations.

4.2.6. Annualised total costs

These benchmark costs include labour costs, fixed and variable operating and maintenance costs and annualised capital costs. The annualised capital cost is based on the capital cost estimated in the section above, annualised based on the lifetime of the technology using a 5% discount rate and is adjusted for inflation.

Table 4.6. Summary of benchmark annualised costs

Waste management solution	Range of benchmark cost [EUR/t/y]
Mixed waste collection and transfer	36-76.5
Collection of source separated waste and transfer	43.2 -92
Sorting station for clean recyclables	26.5 - 76.5
Plastic recycling facility	48.5 - 87.5
Mechanical biological treatment for mixed waste	53.5 - 81
Incineration with energy recovery	79.5 - 132
Landfilling	25.2 -29.7

Source: Based on (UN Environment, 2016[21]), (Pfaff-Simoneit, 2013[31]) and author's (RWA Group's) own calculations.

4.2.7. Assumptions used for estimating costs

The cost estimates used in this paper are based on the following assumptions:

- In the High Ambition scenario, all countries invest in circular economy solutions to prevent generation of waste in the following way: high policy stringency and EU countries (Group 1), assuming leveraged private spending three times higher than current EU budgets allocated, that is EUR 0.60/capita/year; moderate policy stringency countries (Group 2) EUR 0.42/capita/year (70%), and moderate/low policy stringency countries (Group 3) EUR 0.30/capita/year (50%). These investments are assumed to result in a reduction of plastic waste generation of 5% to 15% in the countries depending on the level of investment.

Capital costs

- Investment costs are calculated for a 10-year period;
- All investments are assumed to happen in 2020, prices are expressed in EUR using 2019 prices;
- No replacement costs are considered. As such, the replacement rate and lifetime of the different technologies are not in this model estimation;
- Global estimates are assumed for the costs of facilities, installations and standard equipment. The assumption is based on the prevalence of several world-wide technology providers that inform the fixed cost component of the capital costs;
- Solutions for collection and disposal are country-specific, including locally available solutions, civil works and labour. Therefore, a range of costs is applied with high-income countries assumed to have higher costs and middle- and lower-income countries lower costs.

Annualised costs

- Labour cost and operation and maintenance cost components are left as indicated by the source studies and are not adjusted for inflation;
- The annualised investment cost component is adjusted for inflation and is calculated using a 5% discount rate. Depreciation and interest payments are included in the calculation;
- In terms of operating costs, the costs of personnel, energy and fuel, consumables, administration, taxes and insurance are considered;
- In terms of maintenance costs, maintenance and repair, spare parts and services are considered;
- Costs are given a linear relationship with inputs in the model;
- Non-tariff revenues are not considered. Therefore, the revenue from the sale of energy or recyclables or resulting indirectly from resource efficiency measures are not included in the study.

4.3. Costing circular economy strategies

Circular economy strategies aim to reduce waste disposal to landfill. Policies include measures to reduce plastic through bans or substitute materials, e.g. with bio-benign materials or digitising formerly physical products. It also includes increasing material efficiency by eco-design for lighter packaging, for extending product life, for dismantling, reusing or repurposing. Many such techniques are in the research, development or demonstration (RD&D) stages, and are yet to be deployed to commercial use globally.

Some examples of investments in circular economy solutions are given in the paragraphs below, by way of evidence of the scale of these investments; however, information is insufficient to draw conclusions on costs per capita or per key performance indicators, such as the cost per tonne of waste prevented. Cost estimates for this study are primarily based on EU circular economy spending estimates.

Relevant information on circular economy initiatives comes from the budgets allocated under financing programmes of the EU. For example, the Horizon2020-financed industrial biotechnology project "P4SB" uses synthetic biology to make plastic-eating bacteria. Other bacteria then process the resulting chemicals to produce ingredients for bio-based plastic. The project is still at the RD&D stage and the potential uptake of the technology in the market, as well as its environmental impact, are still to be determined. This approximately EUR 7 million project is an example of investment in R&D needed to underpin circular economy strategies.[15]

Another such project, also financed by Horizon2020, entitled "ResCom" developed an innovative framework to help industrial companies to design and implement closed-loop manufacturing systems. While the project has already yielded tools and platforms for circularity, their uptake by the industry and results in terms of circularity are not yet clear. Total cost of the project was about EUR 6 million.[16]

Table 4.7 summarises fund allocations under the topic of circular economy within EU programmes.

Table 4.7. EU public funds on innovation in circular economy

Financing programme	Budget in the period 2014-2018 [million EUR]
Urban Innovative Action of the Cohesion Policy Funds	32
LIFE	161
Horizon 2020	305
Total of the above	498
	Specific cost [EUR/capita/year]
All EU financing programmes combined	0.20
Spending assumed in cost calculations	0.30 - 0.60

Source: (DG Environment and European Commission, 2019[17]).

Horizon2020 funds helped to mobilise private financing. LIFE finances up to 50% of the required budget of a project, while the other programmes finance up to 100% of eligible costs. Yearly per-capita costs of EU-level spending are estimated at EUR 0.20 EUR/capita/year. The High Ambition scenario assumes an intensification of this type of spending for all countries and estimates waste prevention between 5 to 10% depending on the country.

The private sector also invests in research and development for circular economy and industrial symbiosis that impact waste prevention. For example, AMCOR, the second largest plastic packaging company in the world, pledged to invest at least USD 50 million to accelerate progress towards a 2025 pledged goal to develop all

[15] project website: https://www.p4sb.eu/.

[16] project website: https://rescoms.eu/.

their packaging to be recyclable and reusable (Amcor GRI, 2019). However, often firms do not publically state financial commitments or cost estimations for achieving goals and/or commitments.

There is currently a lack of clear and standardised circular economy indicators. Several initiatives, including at the level of the European Commission, are developing these indicators, and once these are adopted, better understanding will be gained globally on the efforts, costs and results of the various private and public sector initiatives in the sector. The Ellen McArthur Foundation, a major global player in tackling issues of plastic waste, developed a tool called Circulytics[17], which can be used by companies to measure the circularity across their entire operation.

Community-based initiatives for reusing, repairing, repurposing are observed in countries and these efforts are likely cheaper than the downstream recovery technologies. There is sporadic evidence of such initiatives; for example, UNDP invested USD 43 500 in a community-based circular economy project in Burundi to replace plastic packaging of bananas with banana bark-based packaging, leading –among other results– to avoiding an estimated 3 million plastic bags (UNDP, 2019).However, the evidence on community-based circular economy projects remains insufficient to draw conclusions on investment costs and results.

[17] Available at https://www.ellenmacarthurfoundation.org/resources/apply/circulytics-measuring-circularity.

5. Results

The capital costs required to curb ocean plastic leakage into the ocean are estimated at EUR 54 billion in scenario 1 “Moderate Ambition” and EUR 74 billion in scenario 2 “High Ambition” (Table 5.1). On a per-capita basis, the investment costs range from EUR 0.43 to EUR 20.16 in the Moderate Ambition scenario and from EUR 6.05 to EUR 25.54 in the High Ambition scenario. The High Ambition scenario is more investment-intensive. In both scenarios, Group 1 countries require lower investment as compared to Group 2 and 3 countries in order to achieve plastic pollution prevention.

The annualised costs are EUR 17.5 billion for the Moderate Ambition scenario and EUR 18 billion for the High Ambition scenario. Whilst these estimates are similar, the estimates do not include potential revenues that would be generated from the sale of energy from incineration, recyclables, or the potential savings from resource efficiency. The High Ambition scenario is likely to generate higher revenues than the Moderate Ambition scenario. Per-capita annualised costs range from EUR 0.24 to EUR 6.46 in the Moderate Ambition scenario and from EUR 0.83 to EUR 6.52 in the High Ambition scenario.

5.1. Cost breakdown by technology in the two scenarios

Total cost estimations show that while the High Ambition scenario is more investment-intensive, its annualised costs are comparable to the Moderate Ambition scenario. As well, the benefits, including revenues from secondary raw material and energy recovery are not counted in this exercise. Their addition in future estimates would likely improve the economic feasibility of the High Ambition scenario.

Table 5.1. Total capital and total annualised costs of preventing plastic leakage into the ocean

	Capital costs [EUR 1000]		Annualised costs [EUR 1000]	
	Scenario 1 Moderate Ambition	Scenario 2 High Ambition	Scenario 1 Moderate Ambition	Scenario 2 High Ambition
Innovative circular economy solutions	-	18 873 000	-	1 887 300
Mixed collection and transfer	13 669 000	7 527 000	9 131 000	4 898 400
Source separated collection and transfer	-	6 532 000	-	4 474 200
Sorting post source separation, clean MRF	-	4 730 000	-	1 291 200
Plastic re-processor facility of high-quality PP and PE	-	4 352 000	-	394 200
MBT for mixed waste and RDF production	-	11 365 000	-	1 657 200
Energy recovery	14 499 000	14 019 000	1 916 000	1 684 900
Landfill	25 808 000	6 779 000	6 411 000	1 671 900
TOTAL	**53 977 000**	**74 177 000**	**17 458 000**	**17 958 900**

There are differences observed in the capital costs by type between the two scenarios. Investment in landfill is lower in the High Ambition scenario, estimated at EUR 6.4 billion as compared to EUR 25.8 billion in the Moderate Ambition scenario. In the Moderate Ambition scenario all waste is collected in a mixed system, therefore the investment costs in the mixed waste collection and transfer system are higher than in the High Ambition scenario. In the High Ambition scenario, collection and transfer costs are split between mixed and source separated waste stream. In the High Ambition scenario, EUR 7.5 billion investments are required for mixed waste collection and EUR 6.5 billion for collection of source separated waste, a total of EUR 14 billion.

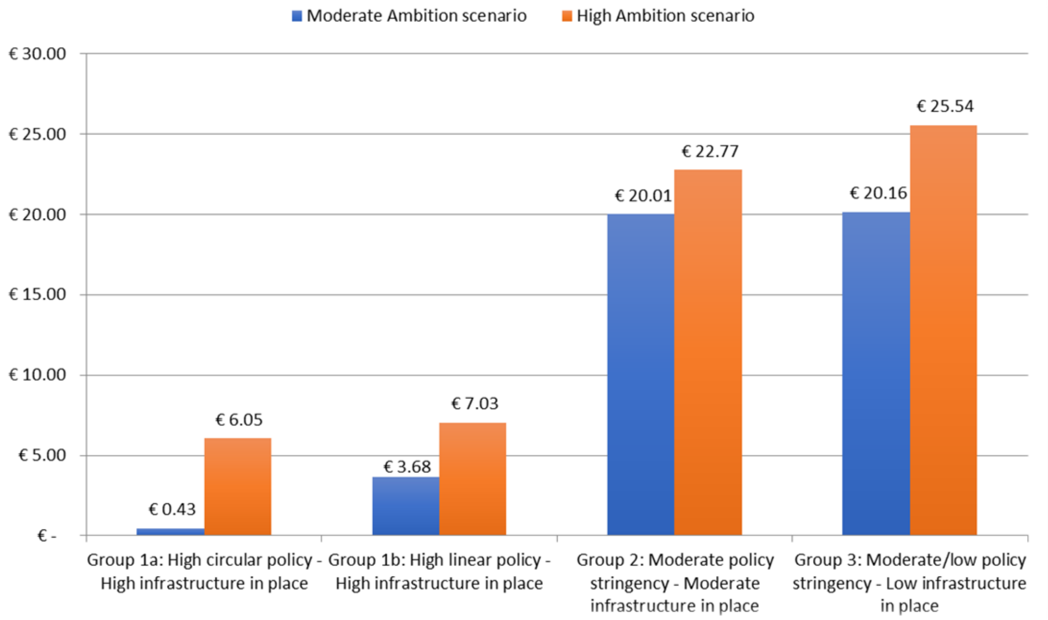
The annualised costs for collection follow a similar pattern in the two scenarios. The High Ambition results in some waste generation prevention through circular economy measures. The Moderate Ambition Scenario results in all investments going into either energy recovery or landfilling. However, in the High Ambition scenario there is a mix of solutions, including investment in recycling.

5.2. Cost breakdown by country groups

The highest per-capita[18] investment costs are estimated in countries with moderate and moderate/low policy stringency, moderate and low infrastructure (Groups 2 and 3), regardless of the scenario chosen (Figure 5.1). This is because the countries in these groups need more essential infrastructure for collection and management of waste. Groups 1a and 1b exhibit a higher capital cost in the High Ambition scenario than in the Moderate Ambition scenario, because these countries have very high capture rates and need a larger investment to build the improvements for the circular economy measures and in increasing resource efficiency of the High Ambition scenario.

Per-capita plastic leakage is lower in Group 2 countries than in Group 3 countries, but investment capacity needs are higher due to relatively higher waste generation rates. In the High Ambition scenario, the solutions for Group 2 countries are more than in Group 3 countries. In the High ambition scenario, Group 3 investments are made in the recycling chain, but collection systems and landfilling remain a significant share of investment.

Figure 5.1. Per-capita investment costs in the two scenarios (EUR/capita)



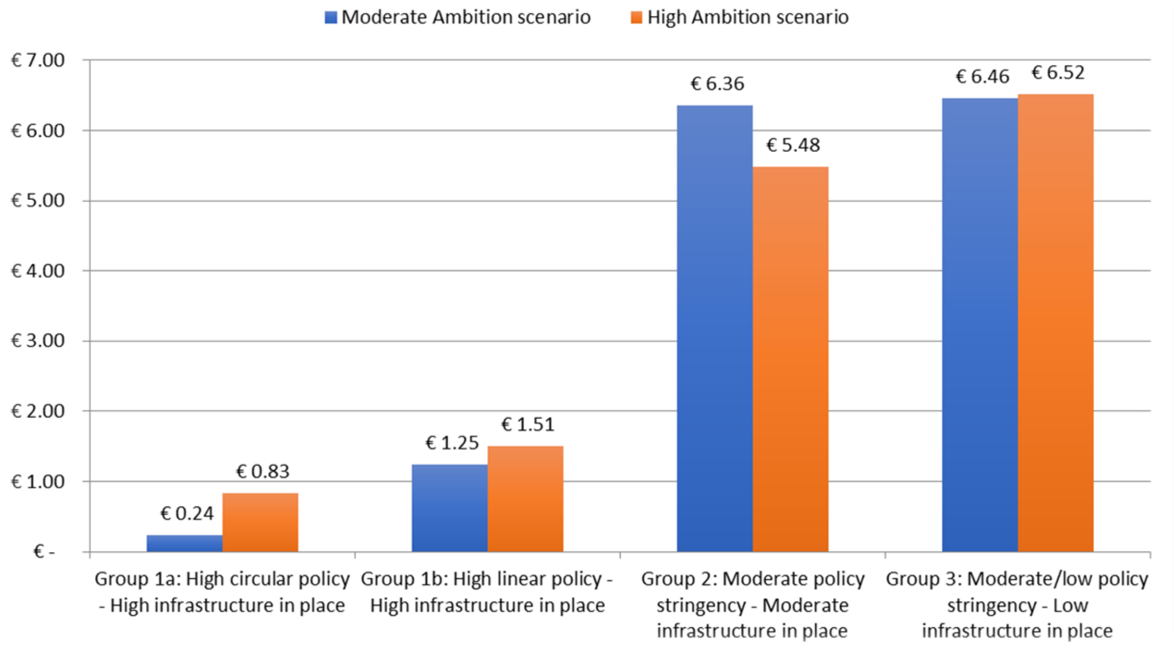
Per-capita annualised costs (10-year planning horizon) are lower than the estimated investment costs (Figure 5.2). As well, the annualised costs are similar across the country groups and scenarios. Revenues from the sale of recyclables and energy recovery are not reflected, neither are savings from resource efficiency. If such revenues were to be considered, this would likely add benefits particularly to the High Ambition scenario.

[18] Per-capita investment costs help to address issues of comparability of investment scenarios due to differences between the population sizes and geography of countries within the different groups.

Low annualised costs in Group 1a countries for the Moderate Ambition scenario reflect the limited need for additional investment in linear measures in these countries. The High Ambition scenario would require further investments, but also provide further incentives for circularity, such as reducing the remaining minimal leakage.

In Group 2, annualised costs are lower in the High Ambition scenario. Therefore, over time the total costs (investment and annualised costs) of the High Ambition scenario are lower for this group of countries. In Group 3 countries, since much of the basic infrastructure is missing and the Moderate Ambition scenario mainly consists of mixed waste collection and landfilling, this scenario is less costly in terms of investment but is very similar in terms of annualised costs, compared with the High Ambition scenario. Detailed country-level results are reported in the Annex (see Annex. Detailed country-level results).

Figure 5.2. Per-capita annualised costs in the two scenarios (EUR per capita)



5.3. Discussion

There are important potential benefits (avoided damages) of adequate waste management (sometimes referred to as economic costs of inaction). Damages and clean-up cost estimates represent significant costs of inaction to prevent plastic waste. A recent study of the economic impacts of ecosystem damage from marine pollution estimates a range for the cost per tonne per year of USD 3 300 to USD 33 000 (Beaumont et al., 2019[32]). The application of the Beamont et al study to the 48 countries sampled in this study yields an estimate of damage of USD 18 to 178 billion per year. The Global Waste Management Outlook estimates the cost of inaction in case of waste management to be about USD 9 to 45 per capita in 2015 (UN Environment, 2016[21]). The clean-up costs estimated in this study's observed countries, without waste management investments to better capture and handle plastic waste, is EUR 11.3 billion per year.

Direct impacts to economies from plastic pollution include damage to fisheries, tourism, real estate values, and public health risks. In 2015, an estimated USD 10.8 billion in damages to fisheries, aquaculture, shipping (transport and shipbuilding) and marine tourism in the 21 Asia-Pacific Economic Cooperation (APEC) economies were attributable to marine debris (McIlgorm, Raubenheimer and McIlgorm, 2020[33]).[19] These annual costs will continue until pollution is addressed with waste management investments.

Similar studies have attempted to estimate the financial requirements to achieve waste management goals. Previous estimates include EUR 28 billion to reach the EU circular economy targets (DG Environment and European Commission, 2019[17]) and EUR 113 billion for global investment demand for waste management infrastructure (Whiteman and Soos, 2011[34]). The two studies had different targets, geographical scope and process flow boundaries, and therefore the comparison with this paper is useful primarily to confirm consistency in the orders of magnitude of the estimates. In addition to a reduction in costs from pollution, a circular economy transition can have positive economic benefits. A 2015 study estimates that a transition to a more circular economy could enable resource productivity to grow in Europe by up to 3% annually and generate EUR 1.8 trillion in annual total benefits (Ellen MacArthur Foundation, 2015[35]).

While cost estimations help design policies to mobilise the necessary public and private finance, investment decisions require assessment of the wider costs and benefits. A wider assessment should include benefits and costs related to environmental, social, economic, and health impacts.

The benefits of the High Ambition scenario are likely far-reaching in terms of improved resource efficiency, reduced greenhouse gas emissions, better pollution control as well as positive impacts on development of business opportunities. Many of these benefits are direct financial revenues while other, more indirect and potentially difficult to monetise, include benefits to stakeholders in the wider society and the population at large.

5.4. Limitations

5.4.1. Plastic waste sources

Both scenarios would theoretically prevent 100% of the leakage arising from uncollected waste and uncontrolled disposal. However, additional investments will be needed to control other sources that are not included in the current study, such as at-sea sources, littering and microplastics (17%). These additional plastic leakage amounts may be estimated with some degree of precision. For example, plastic leakage from littering in Europe is estimated at 170 000 tonnes (Jambeck et al., 2015[5]). However, the solutions and investments needed to control them are either not known or have been difficult to estimate for the purposes of this study.

In case of littering, and leakage from historically illegally or inadequately disposed waste, investments are needed in clean-up actions and in closure of uncontrolled disposal sites. For primary microplastics, regulation to prevent emissions at source may be most effective. For use-based secondary microplastics, measures would be required throughout the lifecycle of products, including end-of-pipe measures such as improved waste water treatment (WWT) and management of storm water.

5.4.2. Costing methodology

The cost calculations are limited to immediate investments. The replacement costs are not factored in for future years or the annualised costs.

The paper estimates investment costs and annualised costs. It is not a cost-benefit analysis because the benefits, including, for example, the revenues generated from recycling in the High Ambition scenario, are not included in the model.

[19] This cost estimate does not include remediation, clean up or ecosystem impacts.

Spatial geography has not been taken into account in the estimations related to mismanaged waste. Recycling, recovery and landfill capacities and costs do not take into account the geographical proximity and associated transport and other logistics costs. They are simplified to work on a unit capacity basis.

5.4.3. Waste-related data

Statistical data related to quantities and composition of waste is limited and frequently inconsistent. For example, the definition of municipal waste varies across countries. In some countries it includes construction and demolition waste that ends up in the municipal disposal site, while in others this stream is excluded and separately managed. Some countries report recycled waste amounts at the point of source separation or sorting, while others report at the end of the value chain at the reprocessing facility.

Furthermore, in some countries composting is included as part of material recycling while in others it is not. Informal sector recycling activities may be as high as 20% but are usually not captured in official statistics. Collection rates are usually known for urban areas but are not reported in rural areas where services may be ad hoc private-to-private arrangements or non-existent. There is a lack of a standardised definition of open dumpsite and various degrees of control at municipal disposal sites, complicating estimates for plastic leakage rates from these sites.

6. Conclusions

This study estimates the gross costs for preventing plastic leakage from land-based, end-of-life macroplastic. Per-capita generation of such leakage varies by country, depending on policy stringency, waste management infrastructure, and plastic waste generation. In countries with high waste policy stringency and extensive waste management infrastructure, plastic leakage is only about 0.20 to 0.40 kg per capita per year. Among the studied country groups, the highest per-capita leakage of 3 kg per year is in the group of moderate policy stringency and moderate infrastructure countries where waste generation rates are high, plastic content in waste is high and the amounts of mismanaged waste are relatively high. In countries with moderate/low policy stringency and less extensive infrastructure, generation rates are low, plastic contents are low but there is insufficient infrastructure to capture the waste, thus leakage averages relatively high at 1.7 kg per capita per year.

Infrastructure helps reduce plastic leakage, but infrastructure alone is unable to solve the problem of plastic leakage. Prevention, a shift to circularity, strong policies and behavioural changes are likely also needed. While cost benchmarks are available for traditional waste management solutions, investment in circular economy solutions such as eco-design, replacement of plastic with bio-benign materials and reduced consumption of plastics is less understood.

Similarly, the measurement of circularity and prevention is still under development, thus the impacts of these investments are also less understood. This paper takes a step further to build these aspects into an investment scenario relying on the current EU budget for circular economy and examples of projects.

The capital costs of the needed infrastructure are estimated in the range of EUR 54 to 74 billion, depending on the level of ambition and complexity. The more linear economy approach including mixed waste collection, incineration with energy recovery and landfilling is less costly in terms of investment than the circular economy approach that includes prevention and high recycling rates.

The annualised cost estimates are at par when looking at all the countries, estimated at EUR 17.5 billion in the Moderate Ambition scenario and EUR 18 billion in the High Ambition scenario. However, this result does not consider any revenues from sale of energy, recyclables or resulting from resources efficiency. Since these revenues are maximised in the High Ambition scenario, it is likely that overall financial gains can be made in this scenario.

For countries with already stringent policies and high recycling rates (Group 1a) the annualised per capita costs are lower in the Moderate Ambition scenario (EUR 0.24 per capita) than in the ambitious High Ambition scenario (EUR 0.83 per capita). This is likely because these countries exhibit high capture rates such that further improvements can mostly be achieved only though more circular economy solutions.

For countries with an extensive infrastructure (Group 1b), implementing an ambitious circular economy High Ambition scenario has similar annualised costs (EUR 1.51 per capita) as in the Moderate Ambition scenario (EUR 1.25 per capita). In this case, considering revenues from recyclables and resources savings would most likely increase the economic feasibility to the High Ambition scenario.

For countries with moderate policy stringency and infrastructure (Group 2), annualised costs of the High Ambition scenario are slightly lower (EUR 5.48 per capita per year) than in the Moderate Ambition scenario (estimated at EUR 6.36 per capita per year). Therefore, over time the High Ambition scenario is less costly. Based on these estimates, Group 2 countries should invest in circular waste management infrastructure if financing is available to support the difference in initial investments.

Finally, countries with low to moderate policy stringency and low levels of infrastructure (Group 3) are currently struggling to capture their waste as the basic infrastructure is missing. Annualised costs in the Moderate Ambition scenario are similar but slightly lower (estimated at EUR 6.46 per capita per year) as opposed to the High Ambition scenario (estimated at EUR 6.52). In these countries, the small difference in costs and anticipated revenues of recyclables can justify investments in line with the High Ambition scenario.

Future studies can expand the cost estimates herein provided. Geographically, future studies can include additional countries, especially in Groups 2 and 3. Coverage can include further sources of marine plastics pollution, including microplastics, use-based loss, littering, or sea-based sources. Additionally, the benefits, including revenues of either scenario can be estimated and help to inform a cost-benefit analysis of waste management investment scenarios.

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Annex. Detailed country-level results

Table A.1. Investment costs and annualised costs in the "Moderate Ambition" scenario

	Moderate Ambition scenario			
Country	Total investment (EUR)	Annualised cost (EUR/y)	Per-capita investment (EUR/cap)	Per-capita annualised cost (EUR/cap/y)
OECD members				
Australia	-	-	-	-
Austria	13,394,000	7,526,000	1.57	0.88
Belgium	7,240,000	4,068,000	0.65	0.36
Canada	-	-	-	-
Chile	45,446,000	17,920,000	2.54	1.00
Colombia	421,808,000	181,118,000	8.67	3.72
Czech Republic	-	-	-	-
Denmark	-	-	-	-
Estonia	11,222,000	6,305,000	8.53	4.79
Finland	-	-	-	-
France	-	-	-	-
Germany	-	-	-	-
Greece	-	-	-	-
Hungary	2,896,000	1,627,000	0.29	0.17
Iceland	-	-	-	-
Ireland	7,964,000	4,475,000	1.68	0.95
Israel	-	-	-	-
Italy	474,944,000	266,861,000	7.77	4.36
Japan	-	-	-	-
Korea	-	-	-	-
Latvia	11,041,000	6,204,000	5.44	3.05
Lithuania	1,991,000	1,119,000	0.66	0.37
Luxembourg	-	-	-	-
Mexico	1,362,200,000	471,914,000	10.82	3.75
Netherlands	-	-	-	-
New Zealand	-	-	-	-
Norway	-	-	-	-
Poland	-	-	-	-
Portugal	42,354,000	23,798,000	3.99	2.24

	Moderate Ambition scenario			
Country	Total investment (EUR)	Annualised cost (EUR/y)	Per-capita investment (EUR/cap)	Per-capita annualised cost (EUR/cap/y)
Slovak Republic	181,000	102,000	0.03	0.02
Slovenia	11,765,000	6,611,000	5.88	3.31
Spain	86,156,000	48,409,000	1.83	1.03
Sweden	-	-	-	-
Switzerland	-	-	-	-
Turkey	1,525,558,000	489,149,000	19.63	6.30
United Kingdom	-	-	-	-
United States	-	-	-	-
OECD accession				
Costa Rica	55,441,000	19,086,000	11.41	3.93
Non-OECD countries				
Mozambique	279,534,000	117,014,000	10.27	4.30
Cameroon	405,636,000	160,434,000	16.09	6.36
South Africa	1,202,673,000	429,108,000	21.20	7.57
Ghana	438,832,000	173,563,000	15.22	6.02
China	7,168,975,000	2,316,543,000	5.17	1.67
India	25,367,611,000	7,874,967,000	18.95	5.88
Indonesia	7,656,436,000	2,458,099,000	29.32	9.41
Philippines	1,361,647,000	440,586,000	13.18	4.26
Thailand	3,565,767,000	990,731,000	51.94	14.43
Egypt	2,447,836,000	940,775,000	25.03	9.62
COUNTRY GROUPS				
Group 1a: High (circular) policy stringency – Highly advanced infrastructure	146,972,000	82,580,000	0.43	0.24
Group 1b: High (linear) policy stringency - Highly advanced infrastructure	7,693,151,000	2,611,065,974	3.68	1.25
Group 2: Moderate policy stringency - Moderate infrastructure in place	8,178,893,000	2,599,026,332	20.01	6.36
Group 3: Moderate/low policy stringency - Low infrastructure in place	37,957,531,000	12,165,437,219	20.16	6.46
TOTAL COSTS	53,976,547,000	17,458,109,525	11.42	3.69

Table A.2. Investment costs and annualised costs in the "High Ambition" scenario

	High Ambition scenario			
Country	Total investment (EUR)	Annualised cost (EUR/y)	Per-capita investment (EUR/cap)	Per-capita annualised cost (EUR/cap/y)
OECD members				
Australia	99,914,000	10,853,130	4.20	0.46
Austria	67,467,000	14,266,489	7.88	1.67
Belgium	74,350,000	12,476,832	6.65	1.12
Canada	149,285,000	17,534,600	4.20	0.49
Chile	132,556,000	28,585,128	7.40	1.60
Colombia	936,975,000	222,991,114	19.26	4.58
Czech Republic	61,386,000	6,138,600	6.00	0.60
Denmark	34,098,000	4,807,560	6.00	0.85
Estonia	22,881,000	8,538,296	17.40	6.49
Finland	32,874,000	4,048,420	6.00	0.74
France	399,744,000	44,469,020	6.00	0.67
Germany	490,116,000	51,309,220	6.00	0.63
Greece	65,352,000	9,081,640	6.00	0.83
Hungary	62,161,000	7,963,743	6.32	0.81
Iceland	1,980,000	273,920	6.00	0.83
Ireland	38,286,000	9,285,433	8.10	1.96
Israel	50,280,000	5,094,770	6.00	0.61
Italy	952,302,000	369,523,804	15.58	6.04
Japan	762,846,000	82,046,000	6.00	0.65
Korea	213,133,000	23,396,020	4.20	0.46
Latvia	24,111,000	8,938,564	11.87	4.40
Lithuania	20,166,000	3,334,504	6.72	1.11
Luxembourg	3,258,000	325,800	6.00	0.60
Mexico	1,516,701,000	341,503,456	12.05	2.71
Netherlands	101,064,000	12,438,860	6.00	0.74
New Zealand	19,706,000	2,163,740	4.20	0.46
Norway	31,134,000	4,187,720	6.00	0.81
Poland	227,916,000	23,642,580	6.00	0.62
Portugal	110,560,000	35,686,021	10.42	3.36
Slovak Republic	33,675,000	3,500,151	6.17	0.64
Slovenia	26,237,000	9,318,984	13.12	4.66
Spain	375,218,000	88,936,440	7.95	1.88
Sweden	58,164,000	7,428,920	6.00	0.77
Switzerland	50,232,000	5,023,200	6.00	0.60
Turkey	1,042,012,000	236,741,128	13.41	3.05
United Kingdom	383,064,000	49,553,740	6.00	0.78

	High Ambition scenario			
Country	Total investment (EUR)	Annualised cost (EUR/y)	Per-capita investment (EUR/cap)	Per-capita annualised cost (EUR/cap/y)
United States	1,911,378,000	215,981,300	6.00	0.68
OECD accession				
Costa Rica	65,594,000	14,863,100	13.51	3.06
Non-OECD countries				
Mozambique	337,601,000	90,077,689	12.41	3.31
Cameroon	546,935,000	163,105,699	21.69	6.47
South Africa	2,055,413,000	514,992,772	36.24	9.08
Ghana	591,050,000	176,676,389	20.50	6.13
China	9,890,909,000	2,974,998,461	7.14	2.15
India	30,722,914,000	8,137,528,378	22.94	6.08
Indonesia	10,107,462,000	2,654,403,802	38.71	10.17
Philippines	2,096,493,000	511,579,555	20.29	4.95
Thailand	3,507,282,000	889,530,647	51.08	12.96
Egypt	3,672,556,000	982,496,337	37.55	10.04
COUNTRY GROUPS				
Group 1a: High (circular) policy stringency – Highly advanced infrastructure	2,080,027,000	285,744,000	6.05	0.83
Group 1b: High (linear) policy stringency - Highly advanced infrastructure	14,714,941,000	3,156,613,000	7.03	1.51
Group 2: Moderate policy stringency - Moderate infrastructure in place	9,306,813,000	2,239,992,000	22.77	5.48
Group 3: Moderate/low policy stringency - Low infrastructure in place	48,075,011,000	12,276,549,000	25.54	6.52
TOTAL COSTS	74,176,792,000	17,958,898,000	15.69	3.80