PLASTIC PAINTS
THE ENVIRONMENT

A global assessment of paint's contribution to plastic leakage to Land Ocean & Waterways

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ABOUT US

EA– Environmental Action research team

EA - Environmental Action is a **mission-driven research consultancy.** It designs solutions and metrics to accelerate the transition toward a sustainable future.

EA consists of a team of **passionate scientists** and **change-makers** and is a member of the European Network of Ecodesign Centres (ENEC).

EA's objective is to create knowledge around plastic pollution, and to develop data and methodologies that enable plastic footprinting and the development of systemic solutions. In the case of paint, given the novelty and importance of the topic, the EA research is also intended to **encourage further studies** to build on this work to generate greater precision on the findings, and to **put paint plastic pollution "on the agenda".**

Publications & Reports

EA has developed a leading expertise in the field of plastic pollution with over **12 related peer reviewed reports and publications** published since 2017 www.e-a.earth/publications.
EA report **"Primary Microplastics in the Ocean"** published in 2017 by IUCN, shed light on the primary microplastic importance (mainly from tyres and textiles) within the plastic pollution arena.

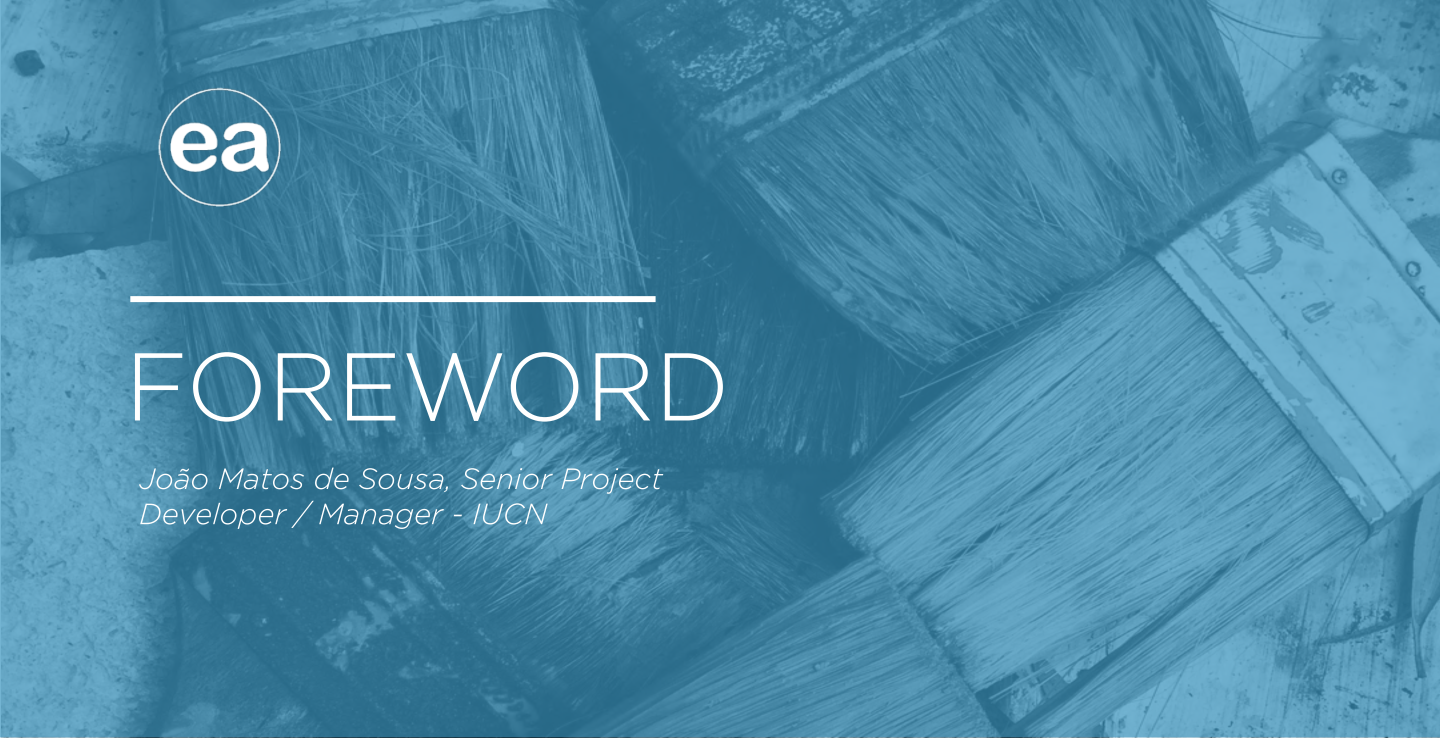
Methodologies

EA has developed the first plastic footprint methodology (**The marine Plastic Footprint,** IUCN 2020) and (**The Plastic Leak Project**, 2020). The approach is now used by tens of leading companies worldwide to assess their plastic footprint.

EA has developed for UNEP and IUCN the **National Guidance for Plastic Pollution and Shaping Action** (2020), now in used by countries to support their effort toward less plastic pollution.

Data Platform

In 2021, EA has launched **PLASTEAX** (www.plasteax.org) the first platform with the intention to disclose best in class polymer specific waste management and leakage data at country level.



FOREWORD

João Matos de Sousa, Senior Project Developer / Manager - IUCN

Humans have been searching for answers for the intangible since the beginning of time. The majority of explanations leaned toward spiritual reasons, while others did not, but in truth, believing in something even when we couldn't see it led to groundbreaking discoveries in physics, chemistry, biology, astronomy, and other fields. Galileo Galilei, Antonie van Leeuwenhoek, Hans and Zacharias Janssen, Robert Hooke, and others are among those who believed that just because we can't see something doesn't mean it doesn't exist.

Fast forward to a not-too-distant past, when the first recognition of the importance of addressing plastic pollution and its consequences prompted rigorous investigation into the causes of this form of contamination. It was necessary to know not only where, when, and how much, but also "what".

Plastic comes in a variety of formats, shapes, and sizes, some of which we can't see but are present in our environment.

Microplastics, little fragments of plastic that have a length of less than 5 mm (0.2 inch) that are found in the environment as a result of plastic pollution, are a part of the problem that has received less attention.

Primary microplastics in the oceans: a global evaluation of sources, published by the IUCN in 2017, was the first time a global assessment of microplastic sources was made available to the public. The report identified textiles and tyres as the leading sources of microplastic leakage (from a primary source), with the leakage anticipated to be on the same scale as that caused by poorly managed packaging.

Since that 2017 IUCN study, many more studies have been published corroborating the importance of addressing microplastic leakage. The microplastic discussion has advanced gaining global traction with much-needed knowledge and increased awareness on the need to address this topic.

With advances in our understanding the microplastics problem, the more we dig, the more we discover. Knowledge is a continuous process, and fresh evidence requires our paradigms and hypotheses to be revised.

The importance of addressing microplastic in Paint in this report shows how pervasive the problem of microplastics is, and not identified in those early assessments. Our understanding of the sources of microplastic is growing and its scope is far greater than previously anticipated.

A key result of this this study is recognizing that primary microplastics released from paint are an even more significant source of pollution than originally understood.

“Plastic paints the environment”.

This report highlights the need for more attention to the problem of microplastics. There are likely to be other equally important sources of microplastic in our environment, and the more we dig the more we will understand and help find solutions to address this human induced problem.

Current literature shows us that consequences of microplastic on biodiversity and human health are negative, and the potential effects of increasingly smaller and invisible particles, such as nanoplastics, may be even more harmful. We are at the tip of the iceberg of knowledge in our understanding the impacts and solutions surrounding microplastics and nanoplastics.

As a result, we must work together to discover solutions to stop the flow of plastic, using a precautionary approach until we know more. By leveraging the science and creating the networks of actors to support the change that is required, solutions to the problems of plastics is in our grasp. The science has demonstrated the problem; now it is up to us to discover ways to restore our rivers and Ocean.

João Matos de Sousa,
Senior Program Officer - IUCN

ACKNOWLEDGEMENT

For this research the EA team would like to thank the network of external scientists and paint industry experts who helped through constructive discussions, validation of assumptions, review of the model and alignment with other research efforts and methodologies.

In particular, we would like to thank the team of reviewers that answered our call for a public consultation process and whose comments greatly improved the quality of the report: Shailendra Mudgal (BioS), Dr Emilia Jankowska (Project Drawdown), Dr Leah Mupas Segui (The Pew Charitable Trusts), Dr Britta Baechler (Ocean Conservancy), Dr Chelsea Rochman (University of Toronto). Furthermore, the authors thank the JRC for providing useful comments to a draft of this report.

Finally, we would like to thank Dr Winnie Lau (The Pew Charitable Trusts), Prof Richard Thompson (Plymouth University), Dr Margaret Murphy, and Dr Luca Nizzetto (Norwegian Institute for Water Research) for the fruitful discussions and precious feedback.

EA– Environmental Action research team

THE EA REPORT STRUCTURE

Targeting the right information to the right stakeholder to shape collective action

1 **Summary**

Key novelty of the work in 10 lines
Target audience : general public, journalists

2 **Executive summary**

High level presentation of the results, conclusions and remaining gaps
Target audience : busy reader, industry stakeholder, scientific journalists

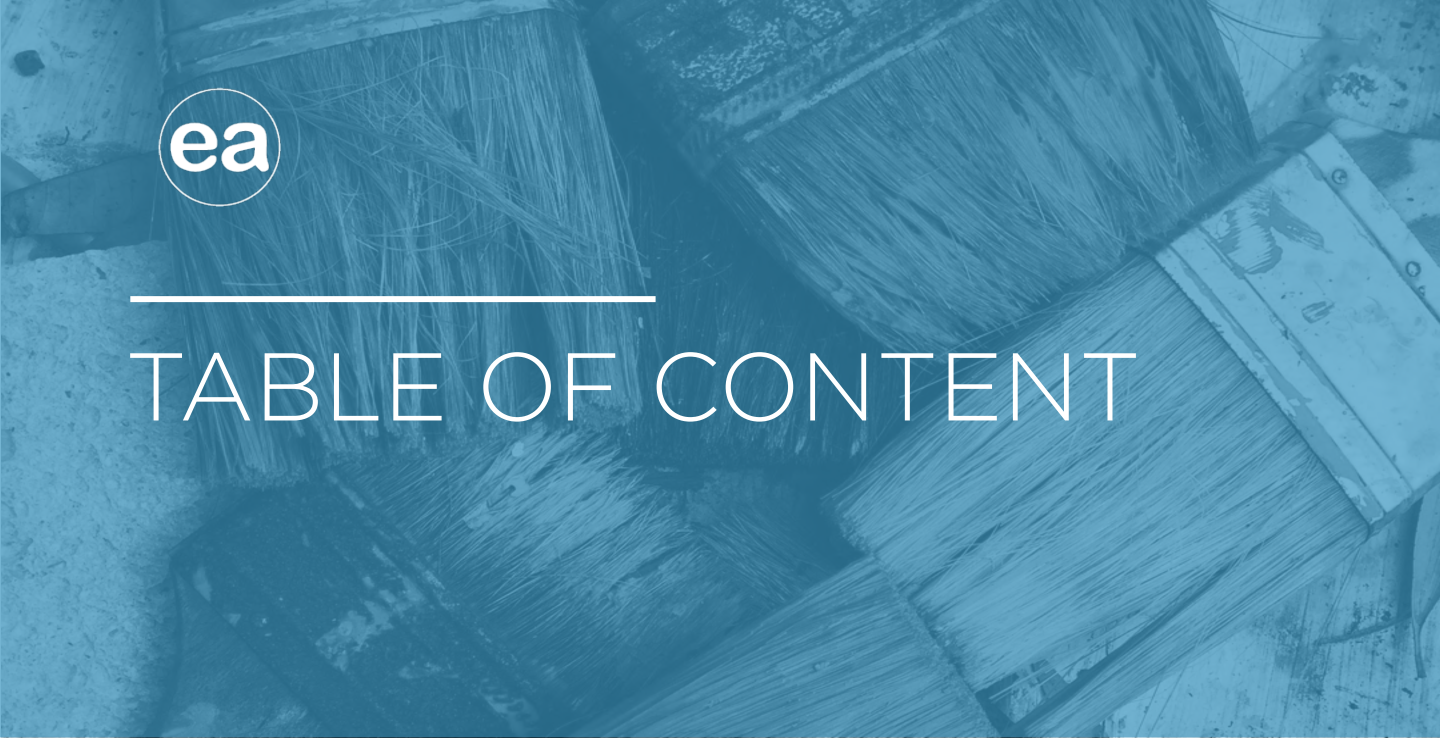
3 **Detailed results**

Detailed presentation of the results, by category
Target audience : scientists, experts

4 **Appendix**

Methodology, supporting data and detailed results including all sensitivity analysis performed
Target audience : scientists, aiming at replicating the study

5 **Bibliography**



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This report provides **a full assessment of the contribution of paint to plastic pollution worldwide**. It is based on the baseline year 2019, with a global paint demand of 52 Mt, that included 19.5 Mt of plastics and was distributed across different sectors: **Architectural, Marine, Road Marking, General Industrial, Automotive, Industrial Wood** and **Others.**

The intention of this research is not to criticise paint, but to increase the level of knowledge and awareness of the issue, so as to pave the way towards a better managed paint system, i.e. a paint system where paint can deliver its full value without compromising the health of our environment.

This report therefore fills a key knowledge gap and provides a new and important insight to enable us to better prioritise research and actions around microplastic leakage, and plastic pollution in general.

Value chain systemic solutions should be developed and implemented by the concerned industries.

SECTION 1

SUMMARY OF THE WORK

Paint is in large part made of plastic polymers (on average 37%).

Leakage of paint to the environment occurs during Application, Wear & Tear and Removal (micro-leakage), or it can be associated with Unused paint or the End-of-Life of the painted object (macro-leakage).

The global contribution of paint to plastic leakage has been largely overlooked so far. The total leakage from paint is estimated between 5.2 – 9.8 Mt/year (with 7.4 Mt/year as central value).

Paint appears as the largest source of microplastic leakage into the Ocean & Waterways (1.9 Mt/year), outweighing all other sources of microplastic leakage (e.g. textiles fibres and tyre dust).

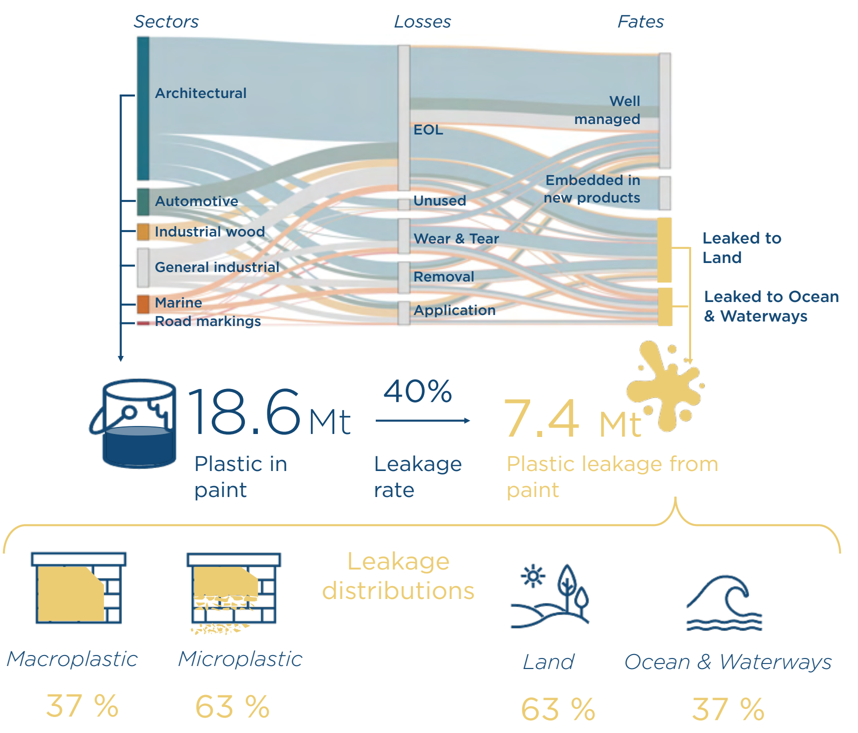


Figure 1. The Sankey diagram shows the flow of plastic in paint from net input on the market by sector to the fates. The analysis is performed on 6 sectors (sector "Others" excluded). Paint can be lost before reaching its supporting material (Application), it can detach from it (Wear & Tear or Removal), or it can be disposed with or without it (Unused, End-of-Life). Ultimately, the lost paint can be Well managed (disposed to sanitary landfill or incineration facility), Embedded in new products, or it can leak to Land or to Ocean & Waterways. The figures are based on 2019 data.

The total contribution of paint to macro and microplastic leakage to the environment is remarkable (mean value of 7.4 Mt/year with a range from 5.2 to 9.8).

A large part of the paint is mismanaged (40%) and thus leaks to the environment. The majority (63%) of this leakage occurs in the form of microplastic, emitted during paint application, maintenance and wear and tear. The remaining 37% of the leakage stems from unused paint or is associated with the end-of-life of the painted objects, thus considered as macroplastics. The **leakage occurs predominantly on Land (63%) and in Ocean & Waterways**.

This is the first study to show that the **paint industry is the sector with the highest contribution to primary microplastics leakage to the Ocean & Waterways (1.9 Mt/year), higher than tyre dust, textile and other known sources combined (less than 1.5 Mt/year in total** (*Boucher & Friot, 2017*; *Lau et al., 2020*). This finding does not mean that these other sectors are not part of the problem too, as the paint leakage identified in this study only adds up to the leakage from these other sources, which was already high in absolute value.

About 37% of the global leakage is the result of different forms of solid waste mismanagement.
The leakage occurring directly in the Ocean (e.g through wear and tear or maintenance of commercial ships or offshore rigs) **accounts for 18% of total leakage.**

Paint leakage is geographically ubiquitous, with leakage rates ranging from 22% in high income North America up to 50% in low and middle income Europe. This means, for instance, that half of the paint applied in European lower income countries will eventually leak to the environment, in one way or another. Because of its larger population, **the highest contribution to total leakage in absolute terms comes from the Asia Pacific region** (54% of total leakage).

The six paint sectors analysed contribute to the total leakage with individual leakage rates ranging from 28% (Automotive sector) to 74% (Road markings sector).
Architectural is by far the largest contributor to the total leakage (48%) and Road Markings is the smallest contributor (2%). In terms of leakage specifically to the Ocean & Waterways instead, the contribution from Architectural paint is similar to that of Marine or General industrial paints.

Paint has a high plastic content - on average 37% - , and can be found on a wide range of objects and infrastructures used in our society: cars, boats, indoor walls, buildings and bridges, among others. This is not without reason **as paint delivers value by protecting objects from environmental degradation and corrosion**. Thus, by increasing the lifetime of objects, paint eliminates the need for frequent replacement or maintenance that would otherwise be necessary, with the associated environmental impact it entails.

SECTION 2

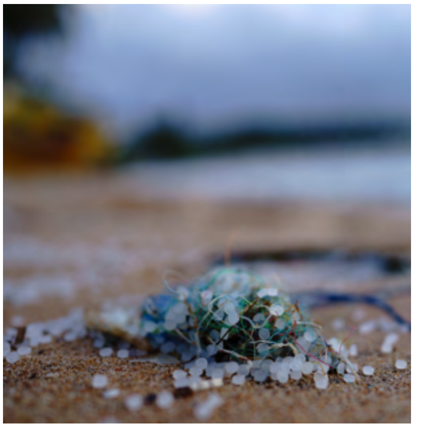
EXECUTIVE SUMMARY

Why assess the plastic leakage from paint?

Over the last decade, plastic pollution has become a major environmental concern. The global plastic leakage to the oceans is estimated to be of the order of 10 Mt (million tonnes) per year (*Jambeck et al., 2015*; *Boucher et al., 2020*) and several fold more when leakage on Land is included (*Lau et al., 2020*). **The magnitude of the environmental and health impact of this ubiquitous environmental contamination is still currently an area of debate, research and concern.**

The sources of plastic leakage are multiple but result mainly from two mechanisms: the leakage of macroplastics primarily stemming from mismanaged waste (*Jambeck et al., 2015*) and the leakage of primary microplastics (*Boucher & Friot, 2017*), predominantly originating from abrasion mechanisms as well as voluntary/involuntary spills. **Microplastics, in contrast to macro-plastics, are plastics that measure less than 5mm.**

Within this category one should distinguish primary microplastics, which are plastic particles or fibres entering the environment already in a micro format, from secondary microplastics, which result from the fragmentation of bigger objects/waste (macroplastic) after they have been exposed to the environment (*Boucher & Friot, 2017 & Lau et al., 2020*). In this report only the primary microplastic and the macroplastic categories are identified.



In this report we use the term "microplastics" to refer to primary microplastics. Since 2010, several studies have assessed the contribution of different sources to total plastic leakage to the ocean (for a review, see *Ryberg et al., 2018; Hann et al., 2018; Boucher et al., 2020; Lau et al., 2020*), showing that global leakage is dominated by macroplastic from mismanaged waste (around 80% of the total), with primary microplastic accounting for around 15% of the total, and ocean sources (lost fishing nets) for around 5% (*Boucher & Friot, 2017; Ryberg et al., 2018*).

These studies indicate very pronounced regional differences: while in Lower Income (LI) countries the leakage mostly stems from macroplastics, in High Income (HI) countries it mostly stems from microplastics (*Boucher & Friot, 2017*). Tyre dust, textile microfibers and primary production pellets are generally cited as the main sources of microplastics (*Lau et al., 2020*).

Some of the previous studies on plastic leakage have also included paint under "other sources" of primary microplastic in the environment. **The contribution of paint to the total microplastic leakage was estimated to range from 9.6% to 21%, depending on the study** (see Table 1).

Although none of the studies takes into account all paint sectors and all geographies, this alone is not enough to explain the difference with our assessment.

The root differences are rather that not all loss types are accounted for in previous studies, and that Wear & Tear and Removal rates are very different. For example, the Eunomia report (*Hann et al., 2018*) excludes all losses due to overspray. Furthermore, most studies base their Wear & Tear and Removal rates on an OECD report (*OECD, 2009*) or on values provided by CEPE (association representing the interests of the coatings sector at European level, see *CEPE, 2021*). For instance, Eunomia estimates that only 0.5% of the antifouling Marine paint will be lost to the environment due to Wear & Tear during the lifetime of the boat, even when most antifouling paint is meant to "erode" or "peel-off" in order to prevent fouling on the boat hull. In this study we assume that within a 4 years period 35% of the antifouling paint will be lost (see the Marine Appendix for more details).

Previous and new results

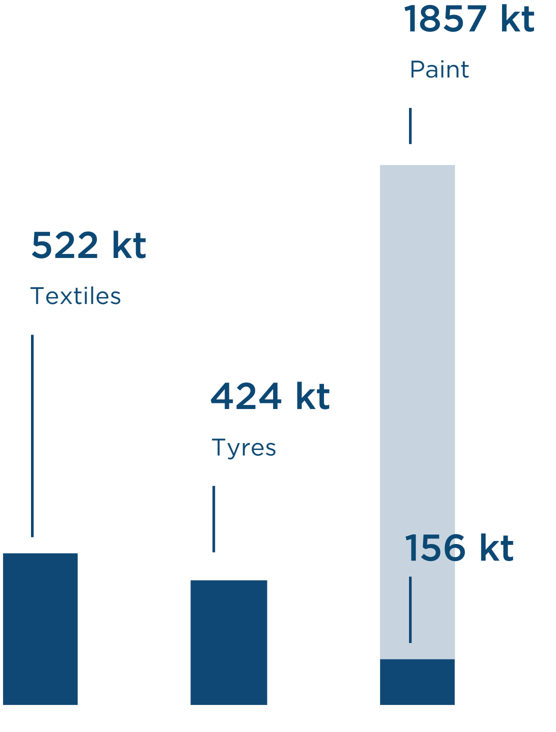


Figure 2. Global microplastic leakage to Ocean & Waterways by source type. Dark blue bars represent the results from the 2017 report by IUCN on global microplastic emissions (*Boucher et al., 2017*), the light blue bar indicates the new updated plastic leakage from paint, based on the current analysis presented in this report. Values are reported in kt.

Source	Geography	Sectors	Paint microplastic leakage (kt/yr)	Per capita equivalent (g/cap/yr)	Paint share of micro-plastic leakage (%)
IUCN *Boucher & Friot, 2017*	Global	• Marine • Road markings	156 (to ocean & waterways)	23 (to ocean & waterways)	10,7%
EUNOMIA *Hann et al, 2018*	EU	• Architectural • Marine • Automotive • Road markings	20 (to ocean & waterways)	40 (to ocean & waterways)	11.6%
MEPEX *Sundt, Schulze & Syversen, 2014*	Norway	• Architectural • Marine • Road markings	1.1 (to environment)	214 (to environment)	14%
UNEP *Ryberg et al., 2018*	Global	• Architectural • Marine • Road markings	640 (to environment)	84 (to environment)	21%
Swedish EPA *Magnuson et al., 2016*	Sweden	• Architectural • Marine • Road markings • General Industrial	1.8 (to environment)	186 (to environment)	9.6%
EA *Paruta et al. 2022*	Global	• Architectural • Marine • Road markings • General Industrial • Automotive • Industrial wood	1'857 (to Ocean & Waterways)	267 (to Ocean & Waterways)	58%

Table 1. Comparison of EA study with previous studies on plastic leakage from paint

Out of the 52 Mt of paint produced globally in 2019, 19.5 Mt are plastic polymers (*MarketsandMarkets Research Private Limited*).

This represented 5% of total world polymer production (*PlasticsEurope, 2020 – 368 Mt*) that year.

"Paints consist of fine, natural or synthetic polymeric binder (or resin) mixed with additives and fillers, that are held together on a surface as a "plastic-like" film when cured [...] Most used paints are based on acrylic, alkyd, polyurethane, epoxy or chlorinated rubber binders" (*Turner, 2021*).

Paint is used ubiquitously to cover a wide range of the objects and infrastructures of our everyday life, therefore incorporating plastic polymers in each of them. Since paint is often applied on exterior surfaces to protect them from wear & tear and corrosion, it should come as no surprise that paint lost during Application, Wear & Tear or Removal will find its way to the environment. Paint has been increasingly identified in environmental samples (for a review see *Dibke, Fischer & Scholz-Böttcher, 2021; Turner, 2021; Turner, Ostle & Wootton, 2022*), highlighting the importance of better assessing the contribution of paint to plastic pollution.

This report intends to fill the knowledge gap around paint plastic pollution by providing a first global estimate of its leakage to the environment.

More specifically we intend to answer the following 4 questions:

1. What is the total contribution of paint to both **micro**- and **macro**-plastic leakage?

2. Which **sectors** are the largest contributors to paint leakage**?**

3. In which **geographies** is paint leakage the most significant?

4. Which are the most important **loss** mechanisms and release **pathways**?

This report thus fills a key knowledge gap and provides new and important insights to better prioritize further research and actions around microplastic leakage, and plastic pollution in general. This report acknowledges the key environmental benefit of paint, which is to protect and increase the life of objects and infrastructures that would otherwise have to be more frequently replaced. The reader must therefore keep in mind that while paint pollution is the topic of this research, our intention is not to criticise paint. **The intention is to increase the level of knowledge and awareness on the issue, so as to pave the way towards a better managed paint system**, i.e. a paint system where paint can deliver its full product and aesthetic value without compromising our environment.

How did we assess plastic leakage from paint?

This research aims to assess the leakage from all of the paint put on the market worldwide, using 2019 as a baseline year. The annual paint production, i.e. 52 Mt in 2019 (*Markets & Markets, 2021, 2019 data*), has been broken down into 7 principal sectors: Architectural, Marine, Road Marking, General Industrial, Automotive and Industrial Wood and Others (see *Section 3* for details). Consequently, system maps have been developed to cover the full life cycle of the paint for all sectors, with the exception of the sector "Others", which was not modelled and accounts for 4% of the paint demand.

The leakage model flows through 4 stages (i) input quantities, (ii) losses, (iii) release pathways and (iv) redistribution fate, while ensuring mass conservation.

The input quantities rely on the plastic content of each type of paint (37% on average from *Markets & Markets, 2021,* based on 2019 data) and on the shares of each type of paint used in the different sectors.

5 paint loss mechanisms have been considered. These include paint lost before reaching its supporting material (Application), detached from it (Wear & Tear, Removal) or disposed with or without it (Unused, End of Life -EOL). Losses at Application, Wear & Tear or Removal (e.g. during maintenance) are considered as losses in the form of microplastic. Losses associated with disposal of leftover paint (Unused) or with the End-of-Life of the painted object are considered as losses in the form of macroplastic (including secondary microplastic).

The release rates and redistribution rates are based on **5 different release pathways**: Ocean pathway, Waste water pathway, Road runoff pathway, Soil pathway and Waste pathways.

The redistribution fate of the plastic is broken into 4 main end-compartments and is then modelled based mainly on the PLP plastic footprinting approach (*Peano et al., 2020*). Paint can eventually leak either to Ocean & Waterways or Land (e.g. soil or dumpsites), be Well-managed (e.g. in sanitary landfills or incineration facilities), or be Embedded in new products (e.g. road marking paint in recycled asphalt or architectural paint in concrete granulates).

The study also considers 5 geographic regions: Europe, MEA, Asia Pacific, Latin America and North America (see *Glossary* for region definitions). Within each of these regions, high income countries (HI) are separated from the others (LI, LMI & HMI) labelled together as "lower income countries" (based on the World Bank classification). Input paint is allocated to these different regions and most of the model parameters are specific to these income levels.

This study has been performed in a **data-scarce context**, as loss rates are poorly documented both in the scientific or grey literature.

The intention of the report is therefore not to provide a precise assessment, but rather to estimate the order of magnitude of paint leakage, in order to determine if paint makes a significant contribution to the total plastic leakage.

For each input parameter, an uncertainty range is considered and a Monte Carlo analysis is performed for each of the modelled system maps. The results of the leakage are then reported as a range with a low and a high value corresponding to the 2% and 98% quantiles. The main results provided in the study correspond to a 95% confidence interval. A 50% confidence interval is also provided.

As the leakage assessment in this study integrates the leakage from the paint brought to the market in 2019 over its lifetime, care must be taken when comparing the results with other activity-based leakage assessments that account only for the leakage occurring in a given year (e.g. when leakage from tyres is based on km driven per year, and leakage from textiles is based on the number of wash cycles per year). However, under a steady state scenario, e.g. no growth in the paint production over time, the production-based and activity-based leakage assessment become comparable, and **the leakage quantities presented can be interpreted as yearly amounts**.

To navigate this data-scarce environment, expert assumptions have been used for some of the model parameters, always with a range of uncertainty provided, and serving as a basis for feeding the Monte Carlo analysis and deriving results within a reliable range of probability. By default, the mean value is used for discussion, with the range provided whenever needed.

All of the **data sources and hypotheses are documented in the *Appendix*** in a fully transparent manner.

We remind all readers that the results of this study and the conclusions have to be interpreted in the light of these input parameters. **We hope and call for further studies to build on this work to increase precision.**

What are the key take-aways ?

RESEARCH QUESTION 1 |

What is the total contribution of paint to both **micro**- and **macro**-plastic leakage?

The total contribution of paint to micro- and macro-plastic leakage is significant (mean value of 7.4 Mt/year with a range from 5.2 to 9.8 Mt/year) and has been overlooked to date by other plastic leakage research projects. The majority of the paint pollution (63%) occurs in the form of microplastic, emitted during paint Application, Removal and Wear & Tear.

The contribution of paint to primary microplastic leakage into the Ocean is higher than the current estimates from textile fibres abrasion and tyre wear.

In spite of the uncertainties arising from the leakage calculation, it is clear from this study that the majority of applied paint do not benefit from proper management during maintenance or end-of-life.

This report shows that the total leakage stemming from all of the paint put on the market in the year 2019 amounts to 7.4 Mt, including leakage to both both Ocean & Waterways and Land. The 7.4 Mt of leakage can be considered as the leakage stemming from the paint put on the market in 2019 over several years or as the yearly leakage stemming from all of the paint in use in 2019, under a steady state scenario (e.g. no growth of the paint production over time).

Leakage of paint as macroplastics from Unused paint and improper End-of-Life of painted objects and infrastructure represent only one-third of the total, with most of the leakage being in the form of microplastics.

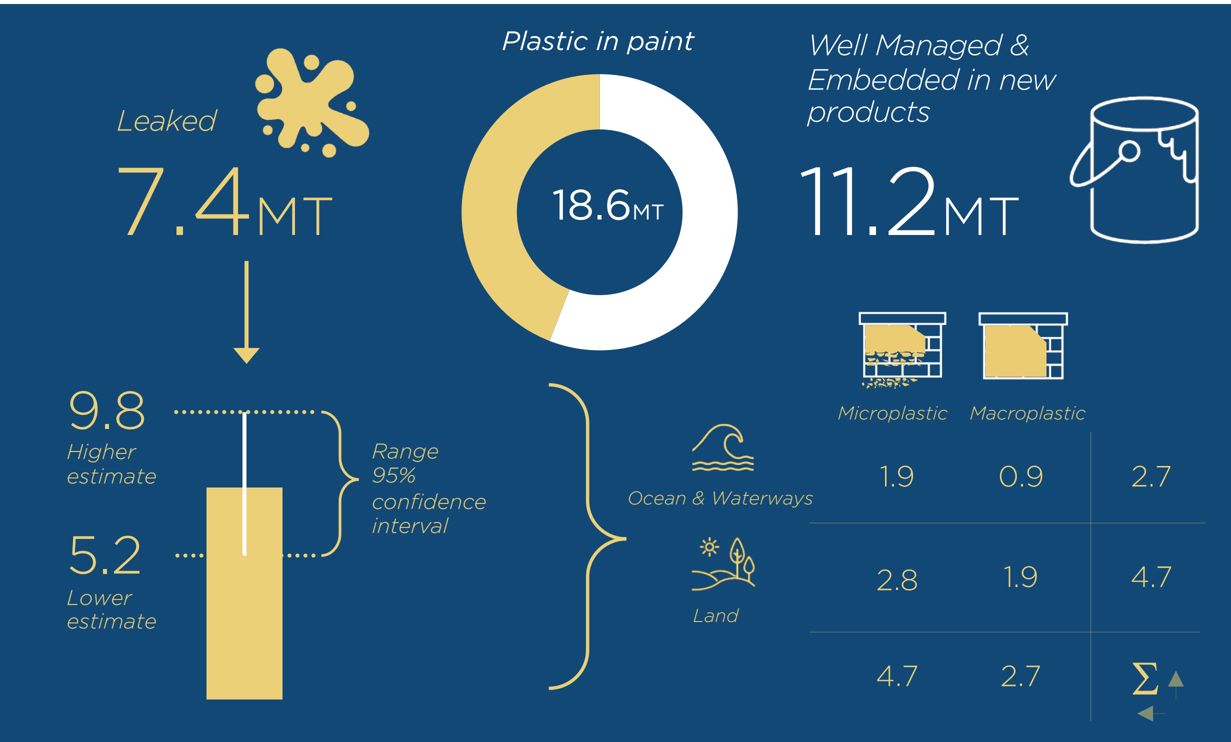


Figure 3. The figure shows the total amount of plastic in paint each year for the 6 sectors and how it divides in leaked and well managed fractions. The value for the leaked fracton is the mean value of a range based on 95% confidence interval. The plastic leakage amount is divided in its fractions of micro and macro plastic and the amounts that end up in the environment (Ocean & Waterways and Land). Sums may not add due to rounding.

Focusing on the microplastic leakage into the Ocean & Waterways, the total leakage mainly stemming from textiles and tyre loss are estimated to range from 1.5 Mt (*Boucher & Friot, 2017*) to approximately 3 Mt (*Ryberg et al., 2018, Lau et al., 2020*). The current study estimates that leakage into the Ocean & Waterways from paint microplastics alone amounts to around 1.9 Mt per year. This makes paint by far the largest contributor to microplastic leakage to the Ocean & Waterways (from 50% to 130% greater than the total from known sources).

Our results indicate that plastic leakage from paint has been overlooked so far because of (1) previous studies not covering all loss mechanisms involved over the paint life cycle and (2) some of the loss rates estimates being low compared to what the latest literature suggests.

RESEARCH QUESTION 2 |

Which **sectors** are the largest contributors to paint leakage ?

The Architectural sector is by far the largest contributor to the total leakage (48%), while Road Marking is the least important one (2%). The highest contribution to marine pollution stems from General Industrial, Architectural, and Marine sector, contributing between 800 to 900 kt of leakage each.

All the six considered sources contribute to the total leakage with leakage rates ranging from 28% (Automotive sector) to 74% (Road Markings sector).

The high contribution of Architectural paint to the total leakage is largely explained by the fact that most of the paint demand is destined to the Architectural (55% of the total).

Input of plastic in paint by sector

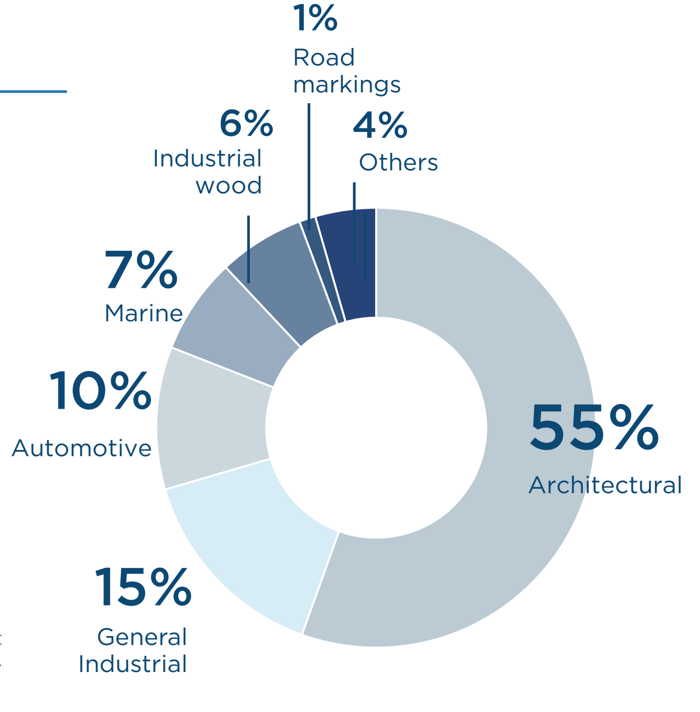


Figure 4. The pie chart shows the yearly input of plastic in paint by sector, data for 2019.

Leakage of paint plastic in the environment by sector

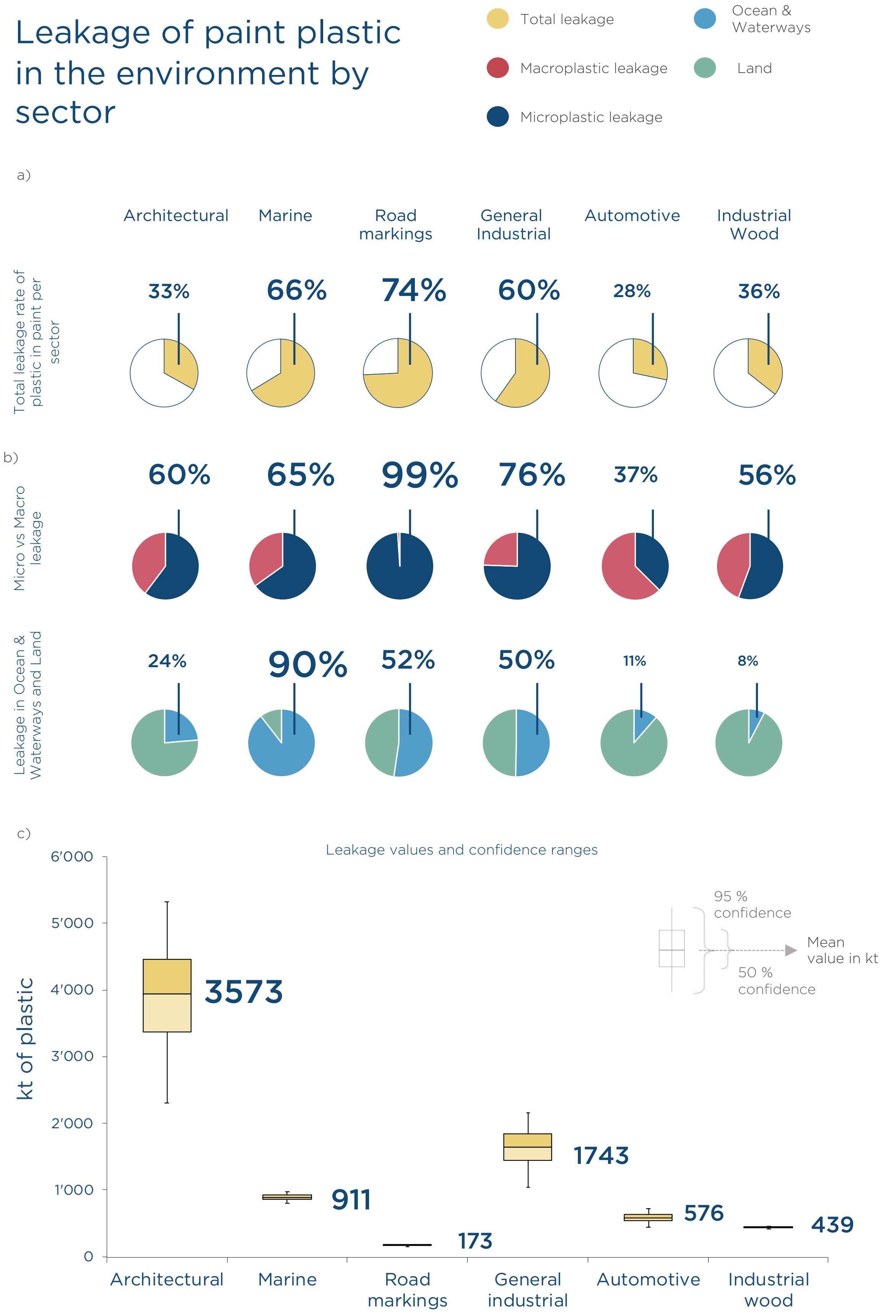


Figure 5. Overview of leakage by sectors: a) Leakage rates for each sector, b) Micro/Macro and Land/Ocean leakage split c) Yearly leakage values confidence ranges.

For all sectors, the microplastic leakage related to Wear & Tear and Removal losses dominates over the macroplastic leakage which is rather due to mismanagement of the painted object at its End-of-Life. The extreme case is the Road marking sector where 99% of the leakage is in the form of microplastic. The only exception to this pattern is the Automotive sector, for which most of the leakage is linked to the improper disposal of vehicles at End-of-Life.

While the leakage from Architectural, Automotive and Industrial wood paints, is mostly distributed to Land, 90% of the leakage from Marine paint is distributed to Ocean & Waterways. For the General industrial and Road markings sectors, the split is roughly 50-50.

RESEARCH QUESTION 3 |

In which **geographies** is the paint leakage the most severe ?

Paint leakage is ubiquitous, with leakage rates ranging from 22% in North America - High Income to 50% in Europe - Lower Income. Due to its larger population, the highest contribution to the total leakage in absolute terms comes from the Asia Pacific region (54% of the total leakage).

In terms of **absolute leakage**, a large fraction of leakage occurs in Lower Income countries in the Asia Pacific region (54% of total leakage), with the second largest contributor being Lower Income countries from the MEA region (12%). The prevalence of the region Asia Pacific - Lower Income on total leakage can be explained with two considerations.

Firstly, this region is home to 50% of the world's population. Secondly, its per capita paint demand is low compare to that of High Income countries, but the mismanagement practices are more pervasive and overall its leakage rate is one of the highest (47%). It is also worth mentioning that 8% of the entire paint leakage in the region, comes from disposal of the world shipping fleet at Ship graveyards on the coast of India, Bangladesh and Pakistan.

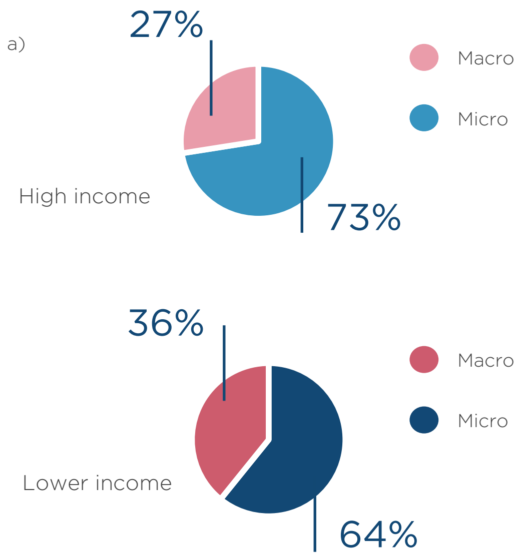
The highest **per capita leakage** is in Asia – High income country, with 1.7 kg/cap/yr against the world average of 1.1 kg/cap/yr. This is mostly due to the fact that 62% of the world shipping fleet is manufactured in South Korea and Japan, and we assume that here is also where 62% of the maintenance during drydocking happens. This alone represents 40% of the region leakage.

The **highest leakage rate** is recorded in Europe Lower income countries (50%) although Asia - LI and MEA Pacific – LI are close behind, with 47% and 46%, respectively. It is worth noticing that the Europe Lower income region includes the Russian Federation, Azerbaijan, Kazakhstan, Kyrgyz Republic, Turkmenistan, Uzbekistan and Tajikistan. Its high leakage rate is mostly linked to mismanagement of waste.

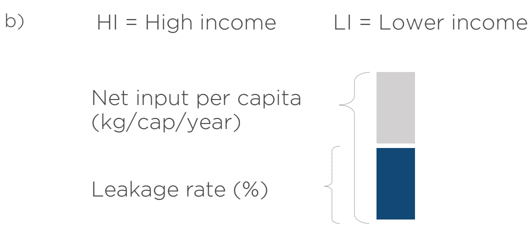
The breakdown between micro- and macro-plastic leakage is quite similar for High Income and Lower Income countries, as the leakage pathways reflect deficiencies in proper solid waste management (affecting the release of macroplastics), in proper wastewater treatment (affecting the release as microplastics), as well as ever present flaws in paint application and maintenance processes.

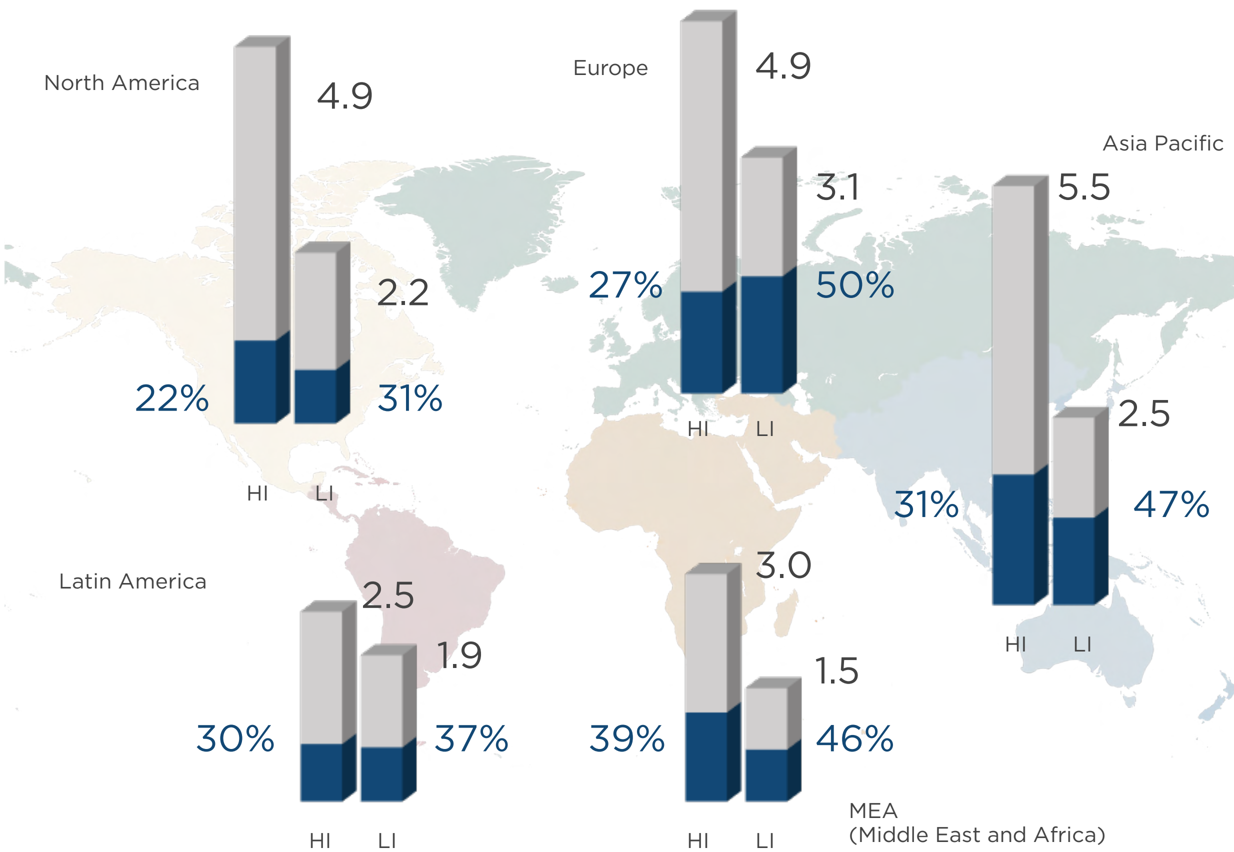
Geographic distribution of the plastic in paint leakage

a)



b)





c)

Total Leakage (kt)	North America	Latin America	Europe	MEA (Middle East and Africa)	Asia Pacific
HI	384	55	662	70	418
LI	88	302	501	918	4018

Figure 6. a) Average micro/macro plastic leakage split for high income and lower income countries. b) Geographical distribution of per capita net input (kg/cap/year) and leakage rates of plastic in paint. c) Geographical distribution of total leakage of plastic in paint (kt/year).

RESEARCH QUESTION 4 |

Which are the **loss** mechanisms and release **pathways** contributing the most to the leakage ?

The paint leakage is mainly due to End-of-Life (34%), Wear & Tear (29%), and Removal (22%) loss mechanisms.

About 37% of the leakage occurs through different forms of solid waste mismanagement. The leakage as direct release to the Ocean (e.g. from maintenance of ships, offshore rigs, bridges, shipyards) accounts for 18% of the total leakage to the environment.

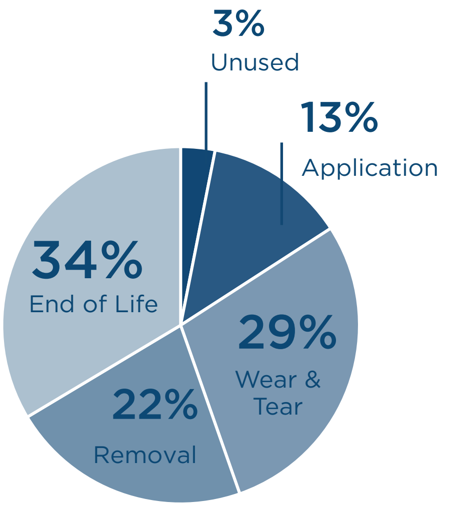
Understanding which loss mechanisms and leakage pathway contributes the most to leakage is key to shaping preventive and remediation actions.

Loss mechanisms

This study modelled 5 types of losses: paint that is lost before reaching its support material (Application, Reapplication), is detached from it (Wear & Tear, Removal) or is disposed of with or without it (Unused, End-of-Life - EOL).

Figure 7 shows that most of the paint that reaches the End-of-Life of the object, or that is Unused, is Well managed, while most of the paint that is lost at Application, Wear & Tear or Removal is mismanaged and leaks to Land or to Ocean & Waterways.

a)



Mapping of paint plastic from Losses to Fates

b)

Losses \ Fates	Leaked to Ocean & Waterways	Leaked to Land	Well managed	Embedded in new products	Tot kt / year
Unused	23	207	629	0	859
Application	357	590	811	0	1757
Wear and Tear	900	1233	510	0	2643
Removal	600	1015	749	0	2364
End Of Life	846	1646	5973	2509	10973
Tot kt / year	2726	4691	8671	2509	

Figure 7. a) Contribution by loss mechanisms to the leakage to Land and Ocean & Waterways. b) mapping of plastic paint from losses to fates

Nevertheless, since most of the paint stays on the object until its End-of-Life, this remains the main loss mechanism to the environment (34% of the total). Losses at Wear & Tear and at Removal contribute to 29 and 22% of the leakage, respectively. When looking solely at leakage to the Ocean & Waterways, Wear & Tear is the highest contributor (33%).

Release pathways

The study shows that 37% of the leakage occurs through different forms of solid waste mismanagement. The leakage through direct release in the Ocean (e.g. through wear and tear and maintenance of ships, offshore rigs, bridges, shipyards) accounts for 18% of the total leakage, the rest being leaked through Soil (24%), Road runoff pathway (17%), Waste water (4%).

For the Marine sector, the leakage occurs mainly through the Ocean pathway (88%). 63% of the leakage to the Ocean from the Marine sector arises from the maintenance and the dismantling of commercial boats (which takes place almost exclusively in low to medium income Asian countries).

26% of Architectural paint leaks due to the mismanagement of Solid Waste. This waste mainly consists of household dust, containing Interior paint lost due to Wear & Tear or Removal processes over the building lifetime. On the other hand, paint left on the building at demolition follows its supporting material at a Recycling facility or an Inert landfill.

Leakage to Soil from the Architectural sector comes from Exterior paint that is weathered or removed over time. Industrial wood solid waste losses are mainly linked to overspray losses at application.

Mapping of paint plastic from Pathways to Sectors

Pathways \ Sectors	Architectural	Marine	Road Markings	General Industrial	Automotive	Industrial Wood	Tot kt
Ocean	1%	88%	0%	29%	0%	0%	1348
Solid waste boat	0%	2%	0%	0%	0%	0%	14
Solid waste	26%	7%	9%	7%	25%	82%	1624
Soil	32%	1%	0%	35%	2%	0%	1771
Road	20%	1%	85%	22%	5%	0%	1285
Waste water	5%	0%	5%	5%	1%	0%	287
Recycling	12%	0%	0%	0%	0%	16%	503
Special waste	4%	1%	1%	1%	6%	2%	234
Inert landfill	0%	0%	0%	0%	0%	0%	0
Automotive waste	0%	0%	0%	0%	61%	0%	350
	100%	100%	100%	100%	100%	100%	

Figure 8. The figure shows the leakage pathways for the different sectors: for example, 5% of the architectural paint leakage comes from the Waste water pathway.

Key conclusions & knowledge gap

Until now, concerns about paint were mainly related to health issues associated with the volatile organic compounds content, the dust generation, or the use of lead paint.

This report clearly shows that plastic leakage from paint has been overlooked to date, as paintnow appears as a major source of microplastic leakage both to Ocean & Waterways and Land.

This finding is not that surprising as paint is ubiquitous and covers a wide range of objects and infrastructures surrounding us. The leakage occurs through different loss mechanisms, which makes the modelling of paint leakage a complex and data intense task. The complexity of the paint loss mechanisms and pathways requires a wide range of solutions for leakage mitigation that may include new paint formulations (e.g. mineral paint), continuous preventive maintenance, better process management of the paint, improvement of the Solid waste and Waste water management systems. The solutions in the case of paint are almost entirely the responsibility of professional practitioners, rather than citizens.

Value chain systemic solutions should be developed and implemented by involving key stakeholders and integrating the full life cycle costs and benefits of possible alternatives.

.

It is important to remember that paint protects objects from environmental degradation and corrosion. Indeed, by increasing the lifetime of objects paint eliminates the need for frequent replacement or maintenance, that would otherwise be necessary and generate additional environmental impacts

The report shows that leakage finds its way both to Land and Ocean & Waterways. The Architectural sector (accounting for 55% of the world paint demand) is clearly the key contributor to the total leakage. When focusing on Ocean & Waterways leakage, the Marine paint sector is a key contributor, mainly from commercial vessels.

We acknowledge uncertainties in the model that affect the way paint flows across the different leakage pathways and is redistributed between Ocean & Waterways and Land; however it is clear from the study that a large part of the paint is mismanaged (40%). This makes the leakage rate from the paint sector one of the highest when compared with the ones from other sectors, for example 1% for textiles and 8% for tyres (*Boucher et al., 2020*).

One key area of improvement in this study, compared to existing literature, is a better understanding of the Wear & Tear losses. EUNOMIA and OECD (*Hann et al., 2018; OECD, 2009*) studies used lower Wear & Tear rates than the ones used here. We consider the loss rates used here are conservative based on the literature and experts consulted (cf. Appendix section for details).

SECTION
2.1

GLOSSARY

Fates
The study considers fate the final compartment where the paint is found. Four types of fates are identified: **Well Managed** which includes incinerator or sanitary landfill, **Embedded in New Product**, **Ocean & Waterways** which includes any body of water and **Land** which includes unsanitary landfills, dumpsites and soil.

Leakage
If not otherwise specified, is intended as the quantity of paint released in Ocean & Waterways and Land. Without further indication this includes both the micro- and macro-components.

Leakage rate
It is the ratio between the leakage and plastic input. This can be defined at each step of the system map.

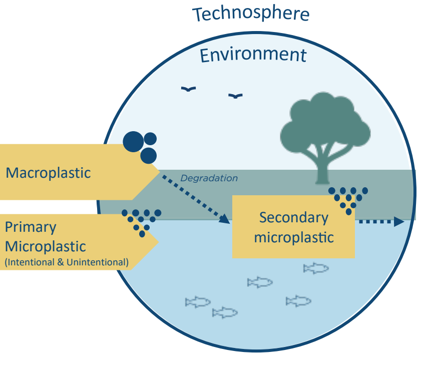
Losses
The loss is defined as the process through which the paint is either:

- Lost → **Application**, Re-application
- Separated from the object → **Removal**, **Wear & Tear**
- Disposed of with the object → End of Life (**EOL**)
- Disposed of without the object → **Unused**

Macroplastics
Large plastic waste readily visible and with dimensions larger than 5 mm, typically plastic packaging.

Throughout this report, the paint that is leaking to the environment in liquid form, or on its support material (i.e. from Unused and EOL losses) is considered macroplastic leakage.

Microplastics
Small plastic particulates below 5 mm in size. Two types of microplastics are contaminating the world's oceans: primary and secondary microplastics. In this study, we focus only on primary microplastics which are plastics directly released into the environment in the form of small particulates. Secondary microplastic is included in the macroplastic leakage.



Mismanaged paint
Paint that is leaked into the environment over its lifetime - e.g. paint applied, handled or maintained without dust/overspray management practices, or that does not benefit from proper waste management when the object reaches its end of life.

Paint
Paint is mixture of pigment, additives and binder (resin) in a solvent which when applied on a surface forms a solid dry film after oxidation, evaporation or polymerization. Most used binders are synthetic polymers such as acrylic, alkyd, polyurethane, epoxy or chlorinated rubber. A paint system usually consists of multiple layers, applied sequentially: a primer (in contact with the support material), an undercoat and a finish coat.

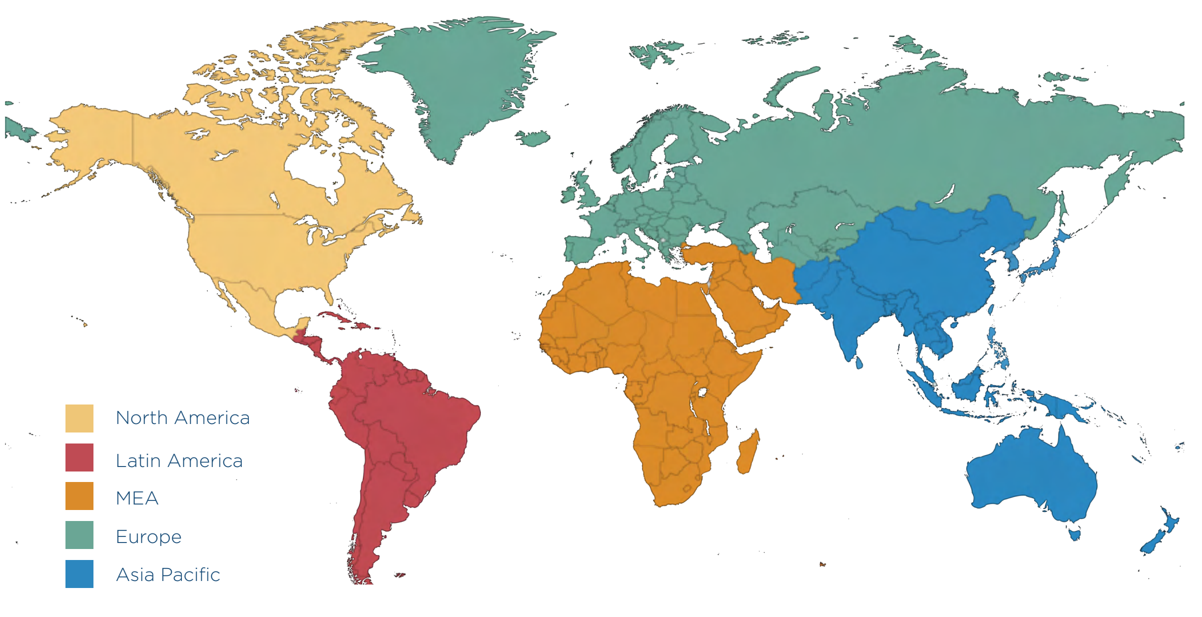
Pathways
In this category are considered the first compartments where paint is lost or disposed to, from which it may get redistributed to various locations.

Plastic demand
Quantity of plastic contained in the paint that is put on the market.

Sectors
The split by sector is based on the ”End Use” of paint, meaning the object type the coating material is applied to, and not on the type of paint technology.

Unit of measurement
All units are in metric tonnes, with kt for thousands and Mt for million tonnes. Unless specified the % are weight by weight (w/w).

Regions
In this study the regions are the ones depicted in the figure: North America, Latin America, Europe, MEA and Asia Pacific. The countries split between high income (**HI**) and lower income (**LI**) is based on the World Bank description, where ”lower income” includes “low”, “lower medium” and “upper medium”.



SECTION
3

DETAILED RESULTS

- Architectural
- Marine
- Road Markings
- General Industrial
- Automotive
- Industrial Wood

HOW TO READ SECTION 3

Section 3 of the report comprises 6 subsections corresponding to the analysis of 6 sectors where paint is used: Marine, Road marking, General industrial, Architectural, Automotive & Industrial wood

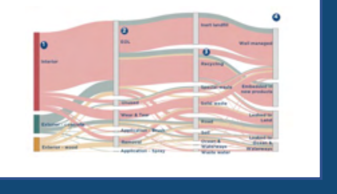
Per each sector the reader will find:

The schemes

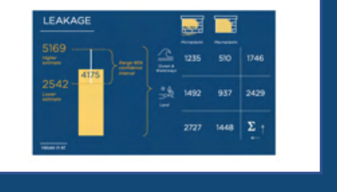
A. **An introductory page** with an overview of the share of paint used in the specific sector related to the total global paint demand, an estimate of the amount of plastic within the paint used in the sector and the corresponding quantity of plastic that is leaked into the environment.

B. **A system map,** showing the stages or categories of the modelling process, from production to fate.

C. **A Sankey diagram** to illustrate how the paint from this specific sector flows across the various stages of its life cycle before reaching its final fate.

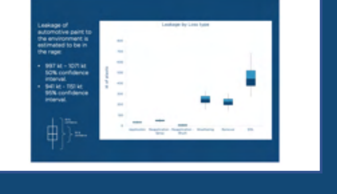


D. **A diagram** which shows how the sector paint contributes to plastic leakage.



E. **A regional analysis** of the paint uses and leakage around the globe.

F. **A sensitivity analysis** which tests a range of uncertainty for most of the modelling steps and assesses the influence on the results.



To be noted: all numbers are rounded to the nearest unit. All references and assumptions are reported in Appendix.

ARCHI-TECTURAL

PAINT USE IN ARCHITECTURE AND ITS IMPACT

Architectural paint accounts for 55% of the global paint demand, amounting to 28.8 Mt.

In 2019, 10'801 kt of plastic were used to make Architectural paint.

33% of the total paint used in the Architectural sector will eventually end up in the environment, including 3'573 kt of plastic. Of this plastic, 844 kt will leak to Ocean & Waterways. 60% of the total leakage will be in the form of microplastic.

In terms of share of paint-related plastic pollution, this represent 48% of the global amount.

Global paint demand

55%

48%

Of global paint-related plastic pollution

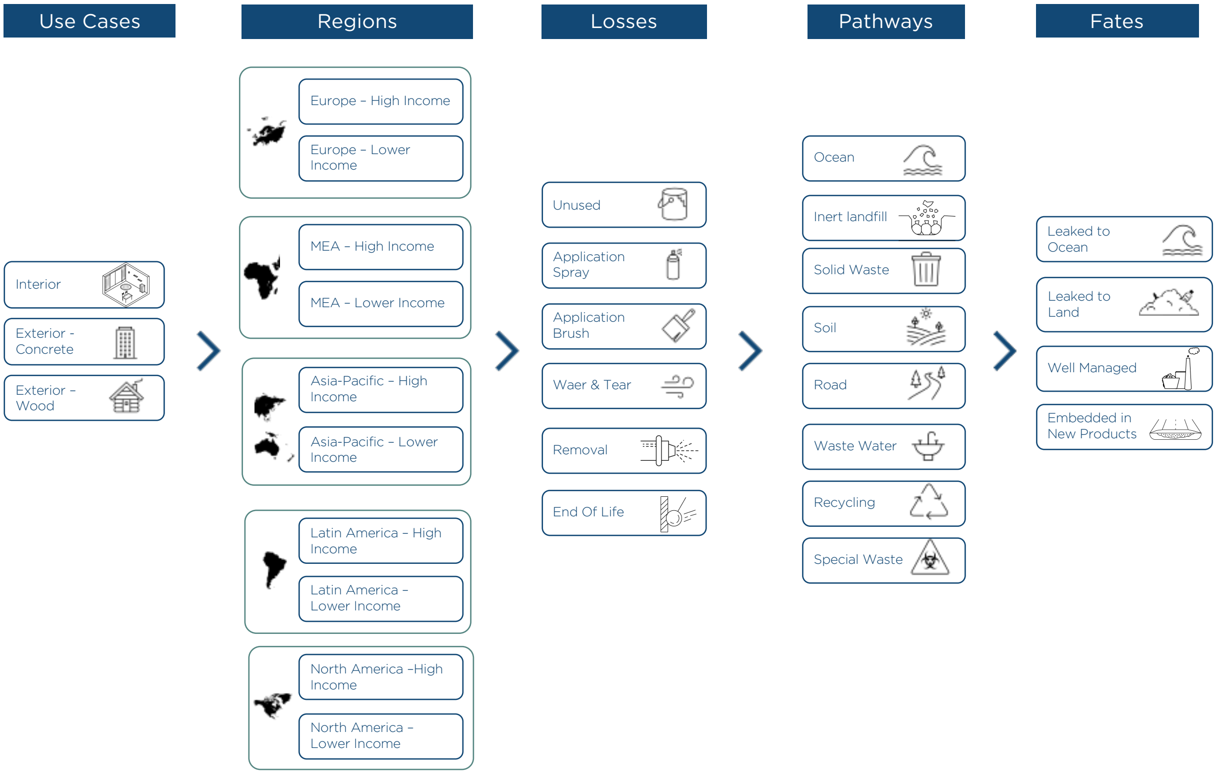
10'801 kt

Of plastic used in production of Architectural paint in 2019

3'573 kt

Plastic lost to Ocean & Waterways and Land due to Architectural paint

PAINT FLOWS IN ARCHITECTURE



The system map, shows the stages/categories of the modelling process, from production to fate.

1. The first category “Use cases” shows the demand of Architectural sector for different use cases: Interior, Exterior – Concrete and Exterior – wood (see Uses table and notes in Architectural appendix for details).

2. The analysis by Regions accounts for the geographical distribution of the paint demand and leakage around the world.

3. The “Losses” category highlights whether paint is lost before reaching its supporting material (Application, Repainting), detaches from it (Wear & Tear, Removal) is disposed with or without it (Unused, EOL).

4. Paint can then find its way into several Pathways, which represent where the paint is being discarded or lost. Inert landfill is a pathway specific to the Architectural paint sector as it can be disposal site for demolition waste.

5. Lastly, the “Fates” provide the distribution of the paint in the four main compartments: Leaked to Ocean & Waterways, Leaked to Land, Well managed and Embedded in new products together with the original supporting material.

ARCHITECTURAL SECTOR PAINT FLOWS ACROSS CATEGORIES

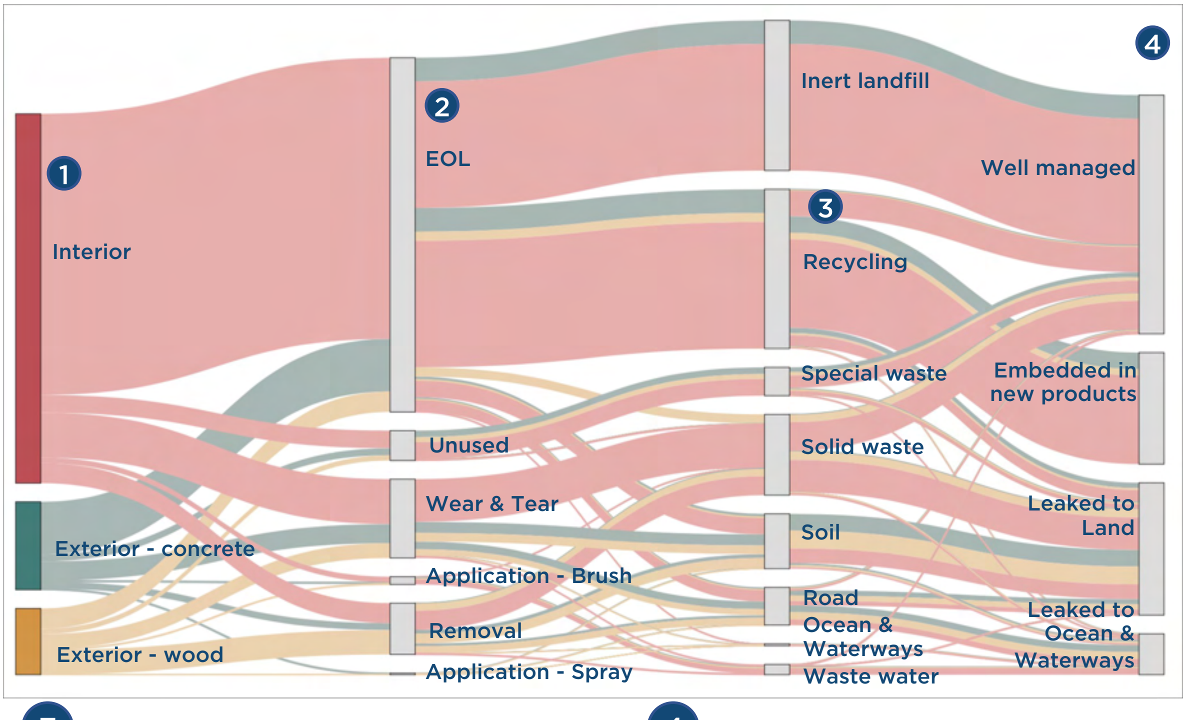
The Sankey diagram shows how architectural paint flows across various categories before reaching its final fate. The Regional analysis is performed in a dedicated section.

1

71% the plastic in paint is used for **Interior** walls. This is intuitively justified by the fact that there is more interior than exterior surface to paint. The figure can change at country level depending on the frequency of repaint jobs for Exterior (closely linked to weather conditions and building material) and Interior walls (linked mostly to aesthetic purposes or reglementary requirements).

2

68% of the paint put on the market in 2019, will still be on the building at its **EOL. 15%** will undergo **Wear & Tear** and **10%** will be **Removed** through cyclical repaint jobs. Although the paint overspray loss rate is high (15%), most of the Architectural paint is applied by Brush or roller and ultimately less than 0.3% of losses happen due to overspray.



3

Recycling refers to the recycling process of the construction material. **30%** of the paint initially put on the market will go through this pathway. At global level, we assume that 50% of the demolition waste will be Recycled. Official figures of Recycling rates are available for concrete (for EU and US), but not for plasterboard, the support material for Interior paint, which represents 70% of the paint market.

4

Overall, **8%** of the architectural paint from 2019, will leak to **Ocean & Waterways, 25%** will leak to **Land, 46%** will be **Well managed** (mostly from inert landfills) and **21%** will be **embedded in new products**, mostly in new plasterboard, but also in concrete granulate (used for road foundations) and, for a small fraction, in plywood or particle boards.

ARCHITECTURAL CONTRIBUTION TO PLASTIC LEAKAGE

In order to have information necessary to be able to tackle plastic pollution from architectural paint, it is useful to look at what are the highest contributors at each step of the system map.

Use cases

Interior paint contributes to 1’778 kt of leakage, while Exterior paints, both on concrete and wood, contribute to 1’796 kt. Exterior paints, though, have higher leakage rates: 46% for Exterior – Concrete, and 71% for Exterior – Wood, against 23% for Interior. Exterior paint has higher chances of leaking because both Wear & Tear and Removal can lead to direct losses into the environment.

	Leakage (kt)	Leakage rate (%)
Interior	1778	23%
Exterior - Concrete	828	46%
Exterior - Wood	968	71%
Total (kt)	3573	

Losses

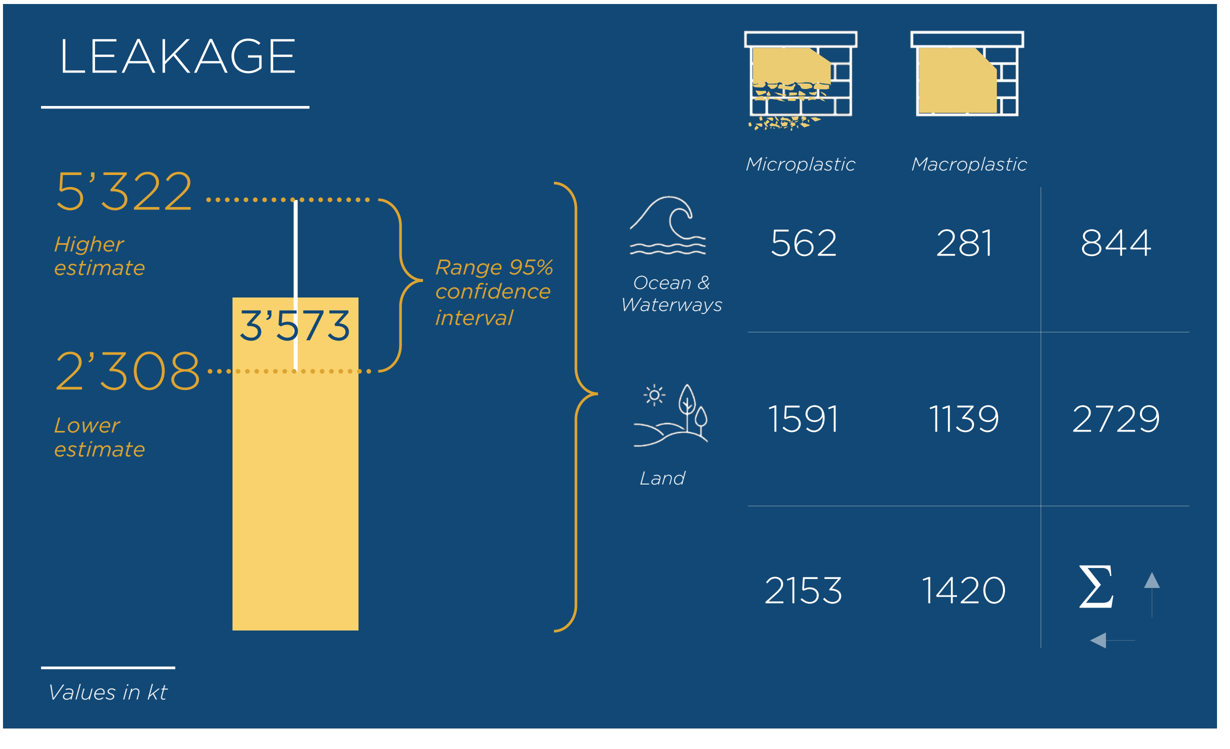
	Leakage (kt)	Leakage rate (%)
Unused	177	29%
Application - Spray	30	95%
Application - Brush	132	82%
Wear & Tear	1201	74%
Removal	792	75%
EOL	1243	17%
Total (kt)	3573	

As already mentioned, most of the paint stays on the building until its EOL. During the renovation or demolition process, 17% of the paint left on the building is estimated to be lost to the environment. Overall, 1’243 kt of plastic leaks to the environment due to EOL losses. An additional 1’201 kt leak due to Wear & Tear, and 792 kt leak due to paint Removal during surface preparation before repainting. Removal happens through sanding, scraping, blasting methods, which remove the paint film from the wall mostly in the form of small dust particles that are then lost to the surrounding environment. In the case of Interior paint, the dust is treated as Solid Waste, while in the case of Exterior the dust is often directly lost to the environment.

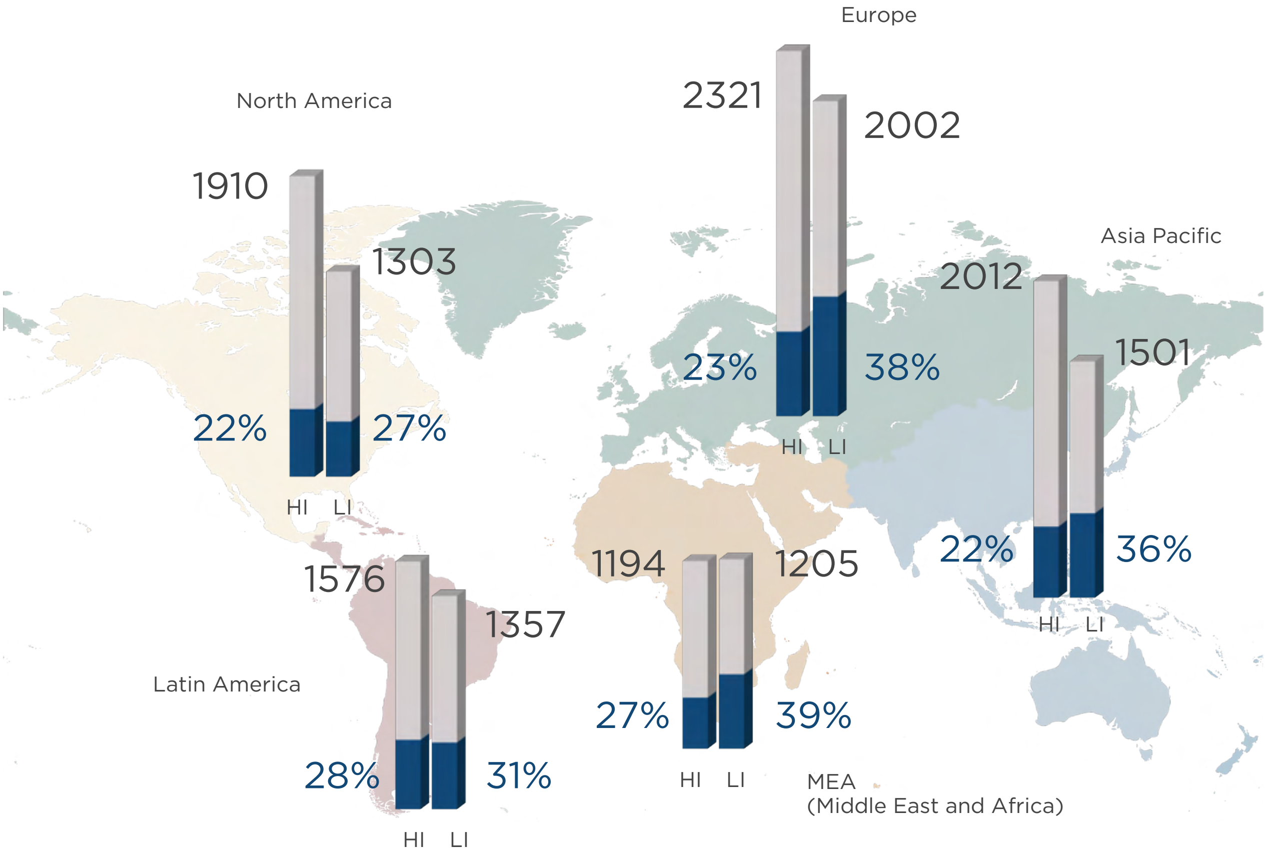
Pathways

Soil is the main leakage pathway with 1'131 kt, followed by mismanagement of Solid waste with 914 kt. This comes mostly from Wear & Tear and removal losses of Interior paint. The third most critical pathway is Road runoff 719 kt. Paint dust lost due to Wear & Tear, Removal or building demolition (EOL) will mostly deposit on Road in urban areas and on Soil in rural areas. According to *EPA, 2016* dust produced during paint Removal through abrasive blasting travels 300-500 meters in the air before depositing.
Note also that there is leakage linked to recycling of painted concrete, wood and plasterboard. This is once again due to dust formation during breaking and grinding process of the support material during Recycling.

Leakage (kt)		Leakage rate (%)
Ocean	39	100%
Soil	1131	100%
Road	719	92%
Solid Waste	914	55%
Waste Water	180	85%
Special Waste	160	27%
Recycling	431	13%
Inert Landfill	0	0%
Total (kt)	3573	



REGIONAL ANALYSIS OF LEAKAGE BY REGION



Net input per capita (gr/cap/yr)

Leakage rate (%)

HI = High income LI = Lower income

TOP CONTRIBUITORS TO LEAKAGE

Absolute leakage:
Asia Pacific – LI, 2’230 kt

Per capita leakage:
Europe – LI, 918 gr/cap

Leakage rate
MEA – LI, 48%

REGIONAL ANALYSIS OF LEAKAGE BY REGION

1 |

53% of the leakage takes place in Asia-Pacific lower income countries, which can be intuitively explained by the fact that 50% of the world population lives there.

2 |

The principal factors in the model that impact the amount of leakage in a region are:

- Paint consumption in the region, which has been attributed based on number of households. As a result high-income countries have a 20% higher per-capita paint consumption than lower-income countries.
- Whether paint is applied by spray or brush/roller, as application by spray leads to higher losses and leakage. We assumed that in lower-income countries paint is almost exclusively applied by brush or roller.
- The state of the waste management system in the region. A poor waste management impacts mostly the leakage to Land, given the use of unsanitary landfill and dumpsites couples with lower waste collection rates. If, on average, the leakage rate of paint to Ocean & Waterways varies only slightly from higher income to lower income countries (7% vs. 8%, respectively), the leakage rate to Land is 18% in higher income countries and 26% in lower income countries.

3 |

The highest per-capita leakage is in Europe – lower income region, with 760 gr/cap of leakage, when the world average is 512 gr/cap. This is due to relatively high number of households given the population, and a relatively poor waste management system.

WHAT IS THE RANGE OF LEAKAGE RATES?

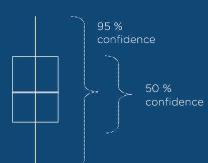
Between 22% in North America - HI and Asia-Pacific – HI and 39% in MEA – Lower Income

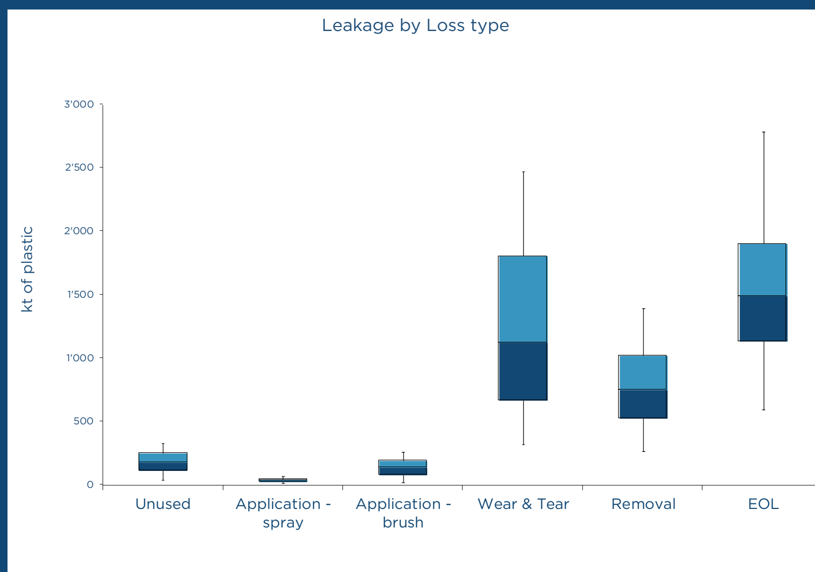
SENSITIVITY ANALYSIS

Modelling the amount of leakage coming from architectural paint required various modelling assumptions. A sensitivity analysis, using Monte Carlo simulations, was performed to test a range of uncertainty of most of the modelling steps and assess the impact on the results. The box plot shows the plastic leakage for the different loss types.

Leakage of architectural paint to the environment is estimated to be in the rage:

- 3.4 Mt - 4.5 Mt 50% confidence interval.
- 2.3 Mt – 5.3 Mt 95% confidence interval.





The highest uncertainty is in Wear & Tear, removal and EOL losses. This is mostly caused on uncertainty on Wear & Tear loss rates and repaint frequency, which then have a cascade effect on leakage due to removal and EOL.

A careful quantitative assessment of the Wear & Tear and removal losses, as well as repaint frequency, would still greatly benefit the accuracy of the analysis, especially if demolition and waste management practices were to improve to reduce leakage from paint at EOL.

Typically a smaller Wear & Tear loss rate leads to smaller removal losses, but to higher leakage linked to the EOL step, and viceversa. As a result, the final uncertainty range for the total leakage is only half of the cumulative uncertainty range of the three steps.

Limitations of the study

Wear & Tear loss rates constitute the main uncertainty of the leakage analysis.

MARINE

PAINT USE IN MARINE SECTOR AND ITS IMPACT

Marine paint accounts for 7% of the global paint demand, amounting to 3.7 Mt.

In 2019, 1'374 kt of plastic were used to make marine paint.

66% of the total paint used in the marine sector will eventually end up in the environment, including 911 kt of plastic. Of this plastic, 816 kt will leak to ocean and waterways.
65% of the total leakage will be in the form of microplastic.

In terms of share of paint-related plastic pollution this represent 12% of the global amount.

Global paint demand

7%

12%

Of global paint-related plastic pollution

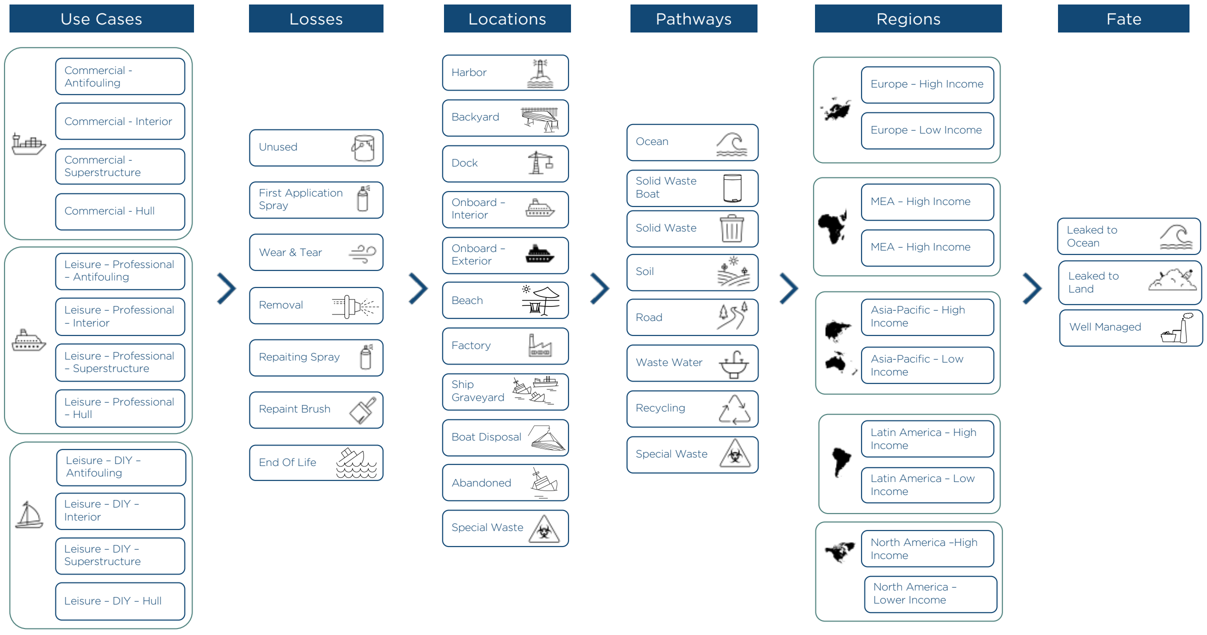
1'374 kt

Of plastic used in production of Marine paint in 2019

911 kt

Plastic lost to Ocean & Waterways and Land due to Marine paint

PAINT FLOWS IN THE MARINE SECTOR



The system map, shows the stages/categories of the modelling process, from production to fate.

1. The first category "Uses Cases" shows the demand of Marine paint by the "Commercial", the "Leisure – Professional" and the "Leisure Do It Yourself" sectors. Each of these sectors is then further divided in subcategories depending on which part of the boat the paint is used: Antifouling, Hull, Superstructure, Interior.

2. The "Losses" category highlights whether paint is lost before reaching its supporting material (application, repainting), detaches from it (Wear & Tear, removal) is disposed with or without it (unused, EOL).The sites (or areas) where the loss can happen are listed in the "Location" category.

3. From the "locations" the paint – and as a consequence its plastic content - finds its way into several "Pathways" which represent where the paint is being discarded or stored.

4. This study also accounted for the geographical distribution of the paint uses and losses all over the globe. This analysis is done and reported in the "Regions" category.

5. Lastly, the "Fates" provide the distribution of the paint in the three main compartments: "leaked to the Ocean & Waterways", "leaked to Land" and "Well managed".

MARINE SECTOR PAINT FLOWS ACROSS CATEGORIES

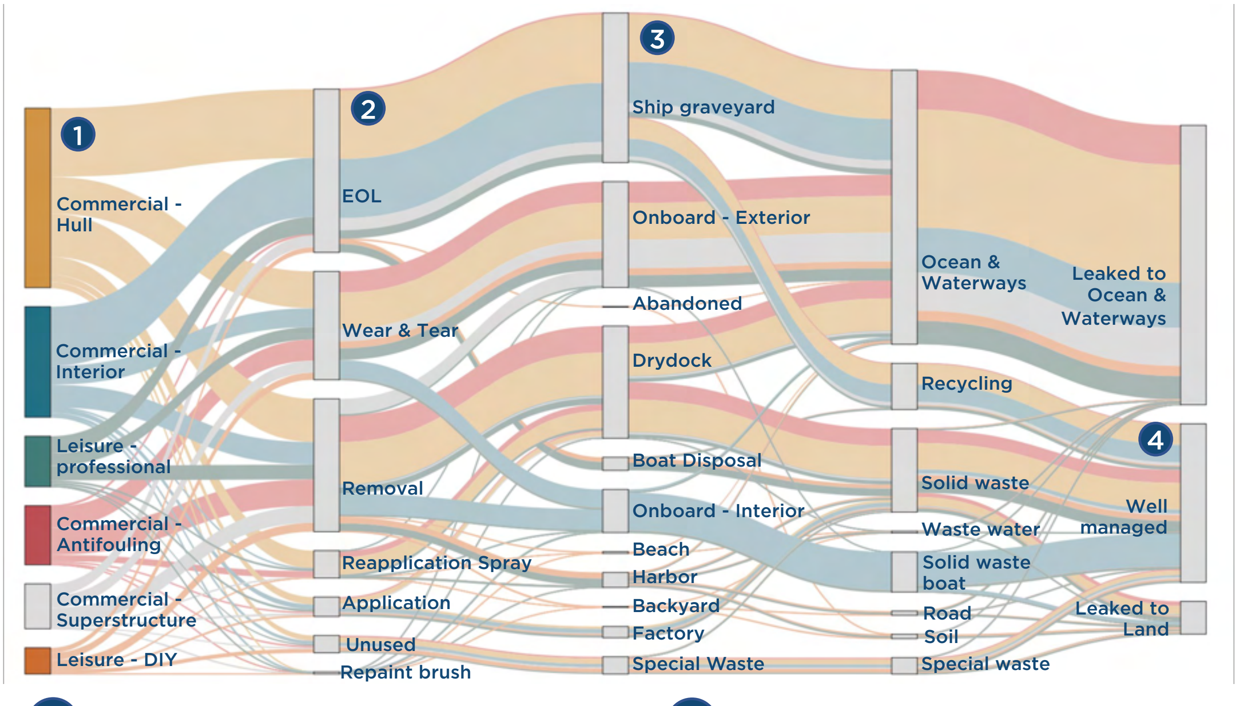
The Sankey diagram show how marine paint flows across various categories before reaching its final fate.

1

Most of the marine paint is used by the **Commercial sector**. This amounts to 84% of the total, "Leisure – Professional" accounts for 11% and the remaining is used by "Leisure – DIY". Within the Commercial sector, **most of the paint is used to paint the Hull.**

2

23% of the paint will be **weathered** during its lifetime, 28% will be **removed** during surface preparation and 35% will still be on the boat when it reaches its **End of Life** (EOL).
Wear & Tear losses happen onboard while the boat is in service. Exterior paint will end up in the Ocean while Interior paint becomes solid waste.
becomes solid waste.



3

Removal of Antifouling and Hull paint of commercial ships happens during **Drydocking**, at least every 5 years. Here, the remaining Antifouling paint is completely Removed and re-Applied, together with a part of the hull paint. If the bottom of the Drydock or floating dock is cleaned before refloating then the Removed paint is disposed to **Solid Waste**, otherwise it's emitted to the **Ocean**.

4

40% of the paint ends up in a waste management stream (Solid waste, Recycling, Waste water, Solid waste of the boat or Special waste for unused paint). Ultimately **only 34% of the paint is Well Managed**, and the remaining is **leaked to the Ocean** or Land.

MARINE PAINT CONTRIBUTION TO PLASTIC LEAKAGE

In order to have information necessary to be able to tackle plastic pollution from marine paint, it is useful to look at what are the highest contributors at each step of the system map.

Use cases

Commercial – Hull paint is the top contributor to plastic pollution to the environment with 374 kt, Commercial – Interior comes second. This is partly due to the fact that Commercial Hull and Interior paint have the biggest shares of the paint market. For Commercial – Interior paint the Wear & Tear losses are smaller than that of other paints and most of the leakage comes from the boat dismantling processes in ship graveyards.
Overall, the Commercial sector contributes to 84.5% of all marine leakage, Leisure – Professional contributes to 10.5% of it and Leisure– DIY to 5%.

Leakage (kt)		Leakage rate (%)
Commercial – Antifouling	129	75%
Commercial - Interior	151	47%
Commercial – Superstructure	113	86%
Commercial – Hull	374	71%
Leisure - Professional	95	65%
Leisure - DIY	49	63%
Total (kt)	911	

Leakage (kt)		Leakage rate (%)
Unused	10	20%
Application	27	48%
Reapplication - Spray	51	63%
Reapplication - Brush	6	93%
Wear & Tear	268	85%
Removal	241	62%
EOL	308	65%
Total (kt)	911	

Losses

In contrast to what one might think, only 29% of the leakage from marine paint is related to Wear & Tear. Most of the losses are due to the ship EOL (308 kt), This is because the world commercial fleet is dismantled in Ship Grayeyards on the beaches of India, Bangladesh, Pakistan, China, and for a small part (3.5%) In Turkey (*UNCTAD, 2017*). Additionally, an important fraction of the leakage comes from losses due to paint removal during surface preparation in drydocks, for a total of 241 kt.

Locations

Onboard – Exterior, gathers the Wear & Tear losses of exterior paint, as well as the removal losses of the superstructure, which for the vast majority become leakage to the Ocean. Onboard – Exterior is the most important contribution to the leakage with 309 kt, or 34% of the total. Losses at Ship Graveyard contribute to 306 kt of leakage.

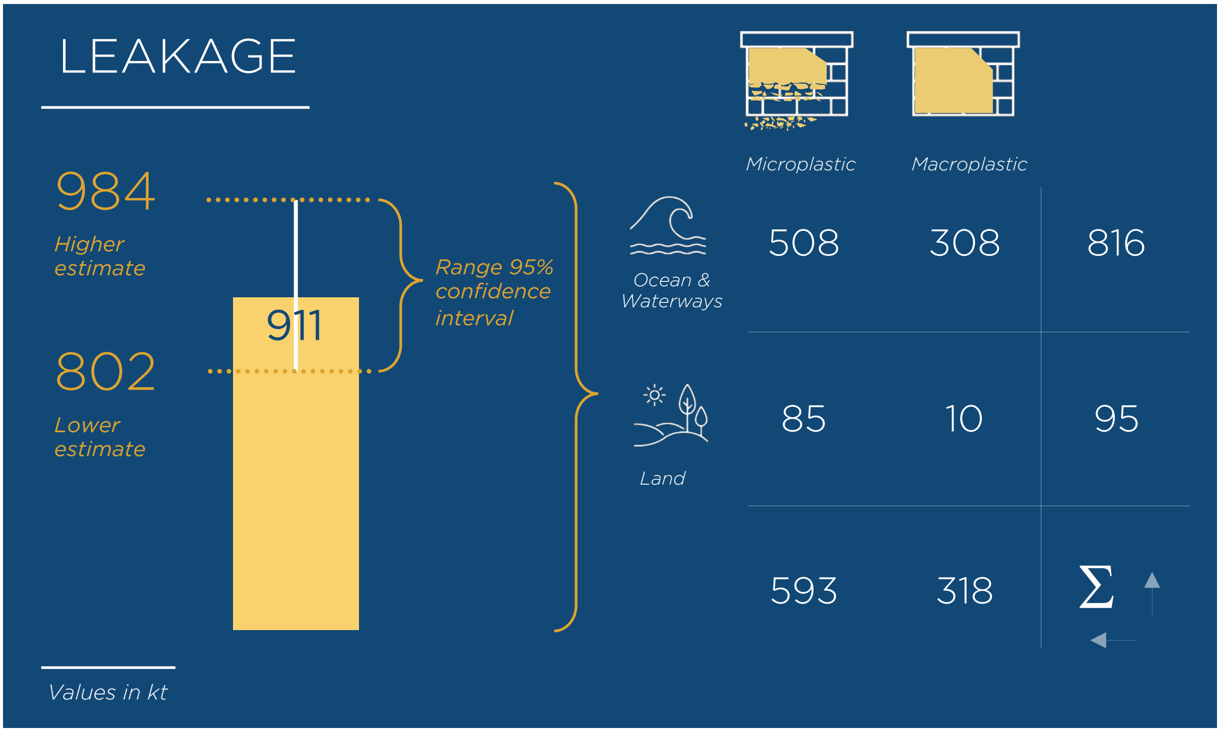
Most of the removal losses happens at Drydock, which contributes to 306 kt of leakage. Little is known about the waste management of paint at drydocks. If sand blasting is used, then paint dust can travel hundreds of meters before depositing (*EPA, 2016*). Whether or not the floor of the drydock is cleaned before refloating the ship, is also crucial in determining the release rate to the Ocean.

Leakage (kt)		Leakage rate (%)
Harbor	30	69%
Backyard	2	91%
Drydock	211	64%
Onboard - Interior	23	19%
Onboard - Exterior	309	100%
Beach	5	100%
Factory	12	37%
Ship Graveyard	306	70%
Boat Disposal	1	2%
Abandoned	1	100%
Special Waste	10	20%
Total (kt)	911	

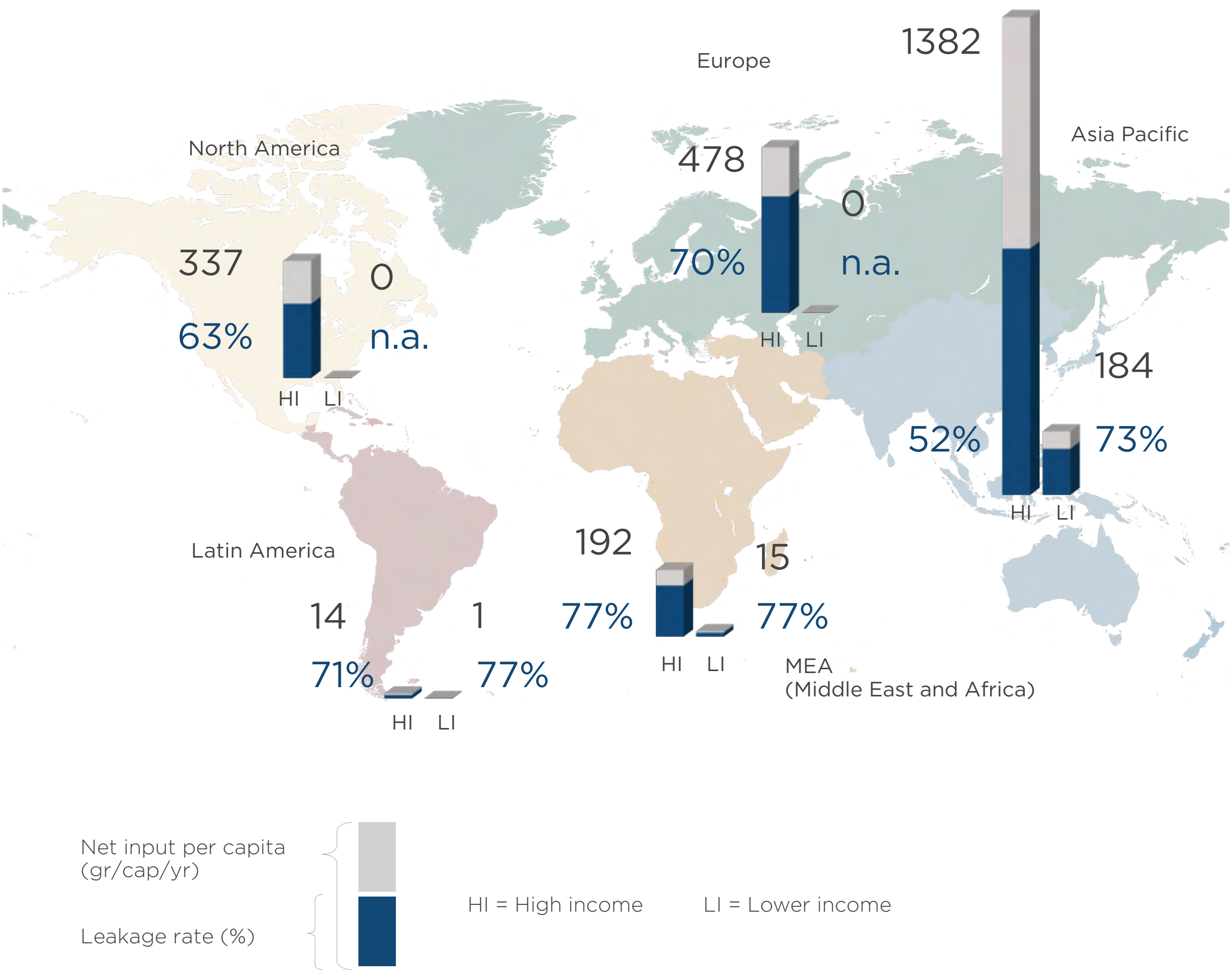
Leakage (kt)		Leakage rate (%)
Ocean	800	100%
Solid Waste Boat	14	12%
Solid Waste	61	25%
Soil	13	100%
Road	10	83%
Waste Water	4	73%
Recycling	0	0%
Special Waste	9	19%
Total (kt)	911	

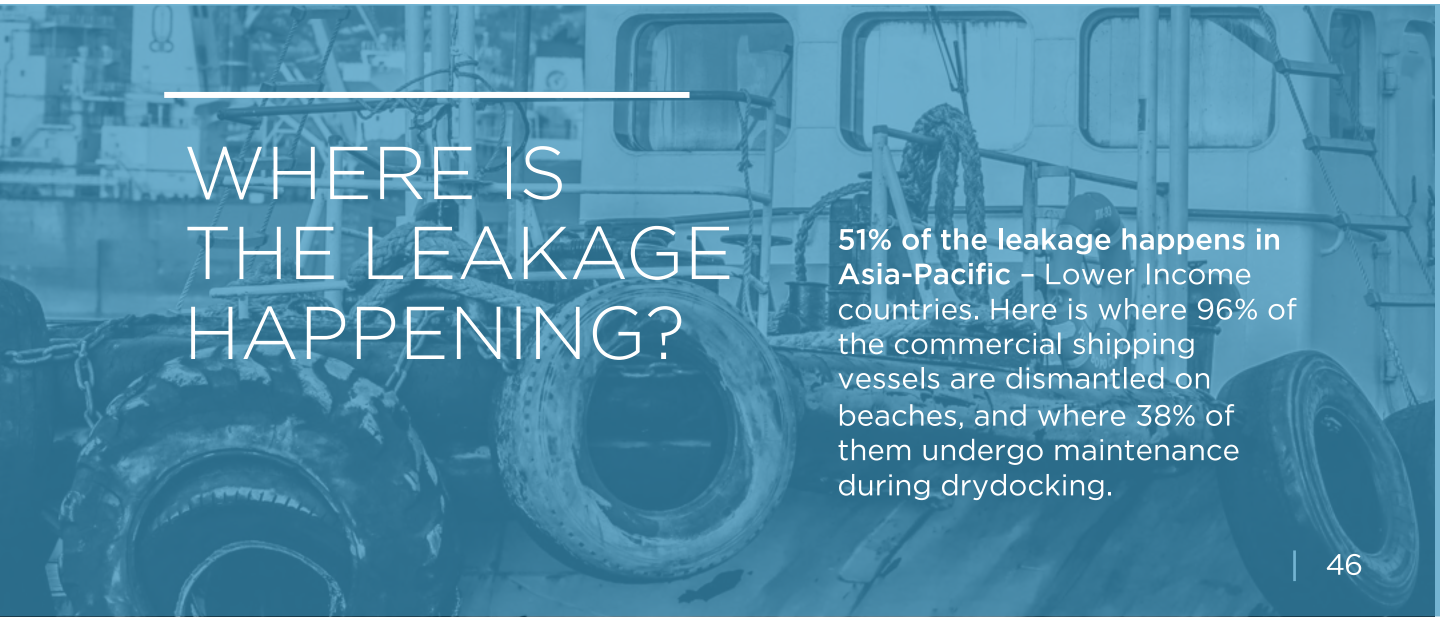
Pathways

The exterior paint lost onboard of the vessel, together with most of the paint that reaches Ship Graveyards at EOL and roughly half of the paint removed at Drydock, are leaked directly to Ocean & Waterways, for a total of 800 kt. Solid Waste and Soil pathways contribution to the leakage are also linked to mismanagement of losses during removal at drydocks or from boat EOL in Ship Graveyard. They also account for mismanagement of application losses at Harbor or Factory.


LEAKAGE
984
Higher estimate
911
802
Lower estimate
Range 95% confidence interval
Values in kt
Microplastic
Macroplastic
Ocean & Waterways
508
308
816
Land
85
10
95
593
318
Σ

REGIONAL ANALYSIS OF LEAKAGE BY REGION





WHERE IS THE LEAKAGE HAPPENING?

51% of the leakage happens in Asia-Pacific – Lower Income countries. Here is where 96% of the commercial shipping vessels are dismantled on beaches, and where 38% of them undergo maintenance during drydocking.

REGIONAL ANALYSIS OF LEAKAGE BY REGION

1 |

Most of the leakage happens in Asia-Pacific – Lower Income countries, where 468 kt of plastic are loss to the environment, i.e. 51% of the world paint leakage

- 96% of commercial ships are dismantled in Ship graveyards in India, Bangladesh, Pakistan, China (*UNCTAD, 2017*). "In Bangladesh, India and Pakistan ships are broken apart directly on the beach instead of in an industrial site" (*NGO Shipbreaking Platform, 2021*). Therefore, a portion of the commercial paint that was left on the ships will be lost to the Ocean.

- Additional losses come from maintenance losses during drydocking. It is assumed that 38% of commercial ships undergo maintenance in Asia-Pacific – Lower Income countries, as this is where 38% of the fleet is built (*UNCTAD, 2017*).

2 |

Asia Pacific – High income countries, specifically Japan and South Korea, come second in terms of contribution to leakage, with 174kt. The region has the highest per capita contribution to the leakage with 712 gr/cap against the world average of 131 gr/cap.

- This is due to Japan and South Korea producing 62% of the commercial world fleet (*UNCTAD, 2017*), and we assume that 62% of the maintenance will happen there.

3 |

Although commercial ship-building, maintenance and disposal happens almost exclusively in Asia, more than half of the shipping fleet belongs to Europe - High income countries, which is responsible for 167 kt of plastic leakage:

- Wear & Tear and Removal losses onboard of the vessel were attributed to the country of ownership, while losses during maintenance at docking or ship breaking are assigned to the country where they take place

- The figures for the Leisure industry indicate that 74% of the world fleet (by unit) belongs to North America – High income, 18% belongs to the Europe – High income and 6% to Asia Pacific– High income (modelled from *ICOMIA, 2017*).

WHERE DO SHIPS COME FROM?

98% are built in Asia
56% belong to European countries
96% are disposed of in Asia

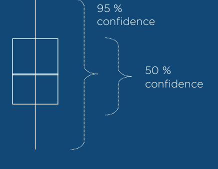
Values from *UNCTAD, 2017*

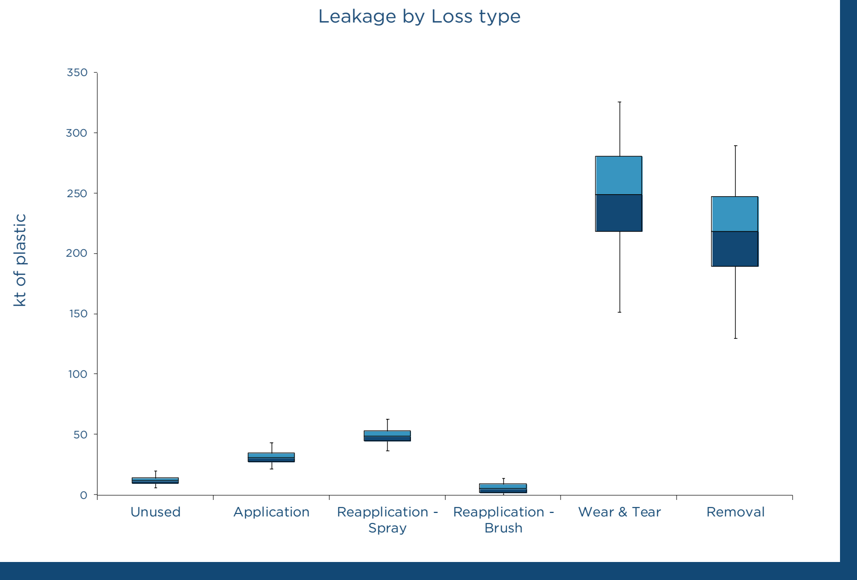
SENSITIVITY ANALYSIS

Modelling the amount of leakage coming from marine paint required various modelling assumptions. A sensitivity analysis, using Monte Carlo simulations, was performed to test a range of uncertainty of most of the modelling steps and assess the impact on the results. The box plot shows the plastic leakage for the different loss types of marine paint.

Leakage of marine paint to the environment is estimated to be in the rage:

- 857 kt – 922 kt 50% confidence interval.
- 802kt - 984 kt 95% confidence interval.





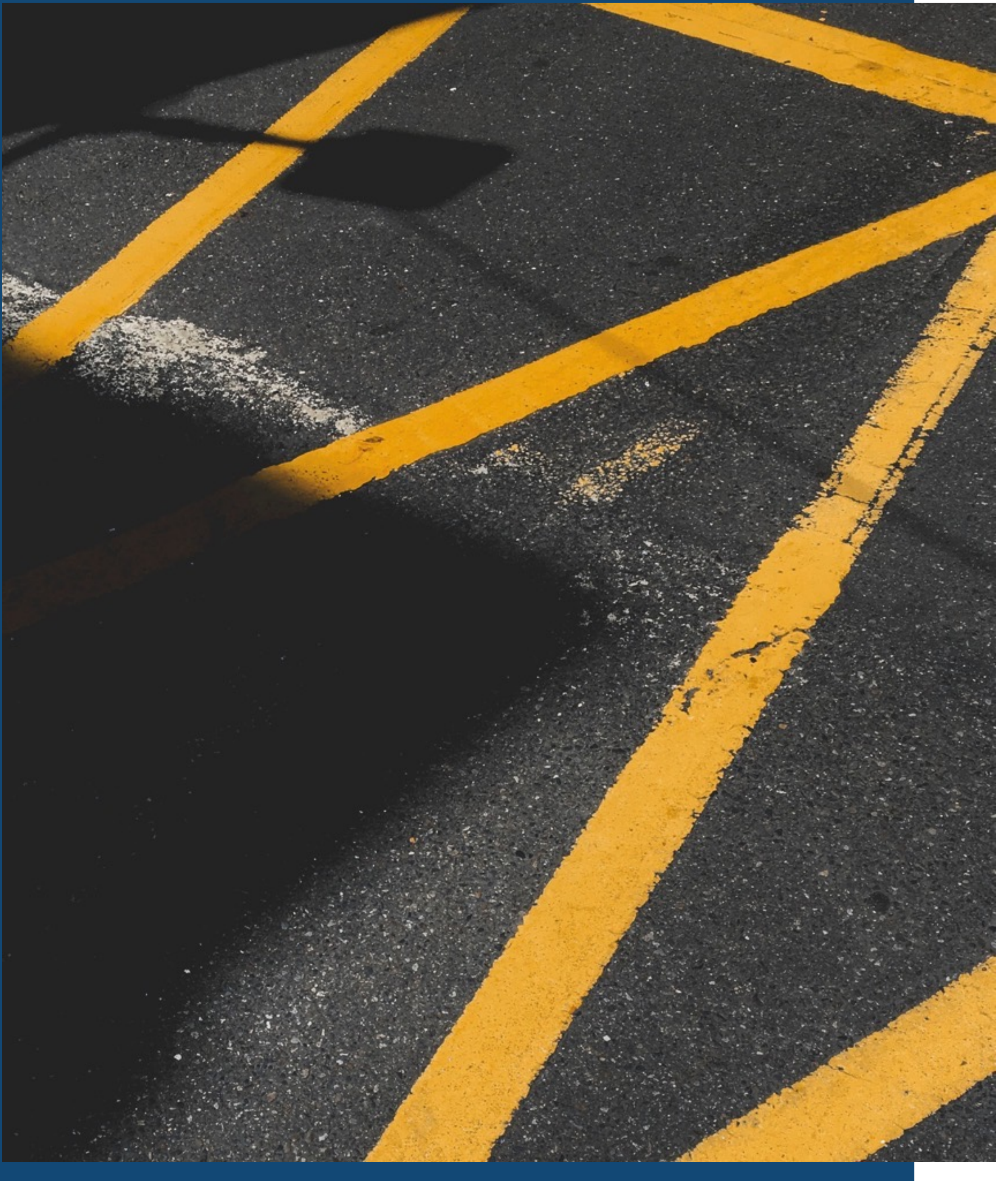
A multitude of factors contribute to uncertainty with the results, but the key ones are:

- Whether or not drydocks floors are cleaned before re-floating (we assumed they are cleaned 50% of the time on average)
- How often re-paint jobs are done and how high is the loss rate of paint due to Wear & Tear between two re-paint jobs. For a deeper insight on the modelling of the Wear & Tear-removal-repaint cycle see the Appendix.

Limitations of the study

The greatest uncertainty is related to the practices of paint Removal during Drydocking. It is unclear whether there are practices in place to prevent the paint that deposits on the floor of the Drydock from entering the Ocean when the ship is refloated.

Literature is also lacking on management of paint at Ship graveyards.



ROAD MARKINGS

PAINT USE IN ROAD MARKINGS AND ITS IMPACT

Road markings paint accounts for 1% of the global paint demand, amounting to 0.6 Mt.

In 2019, 234 kt of plastic were used to make road markings paint.

74% of the total paint used in the road markings sector will eventually end up in the environment, including 173 kt of plastic. Of this plastic, 91 kt will leak to ocean and waterways.
99% of the total leakage will be in the form of microplastic.

In terms of share of paint-related plastic pollution this represents 2% of the global amount.

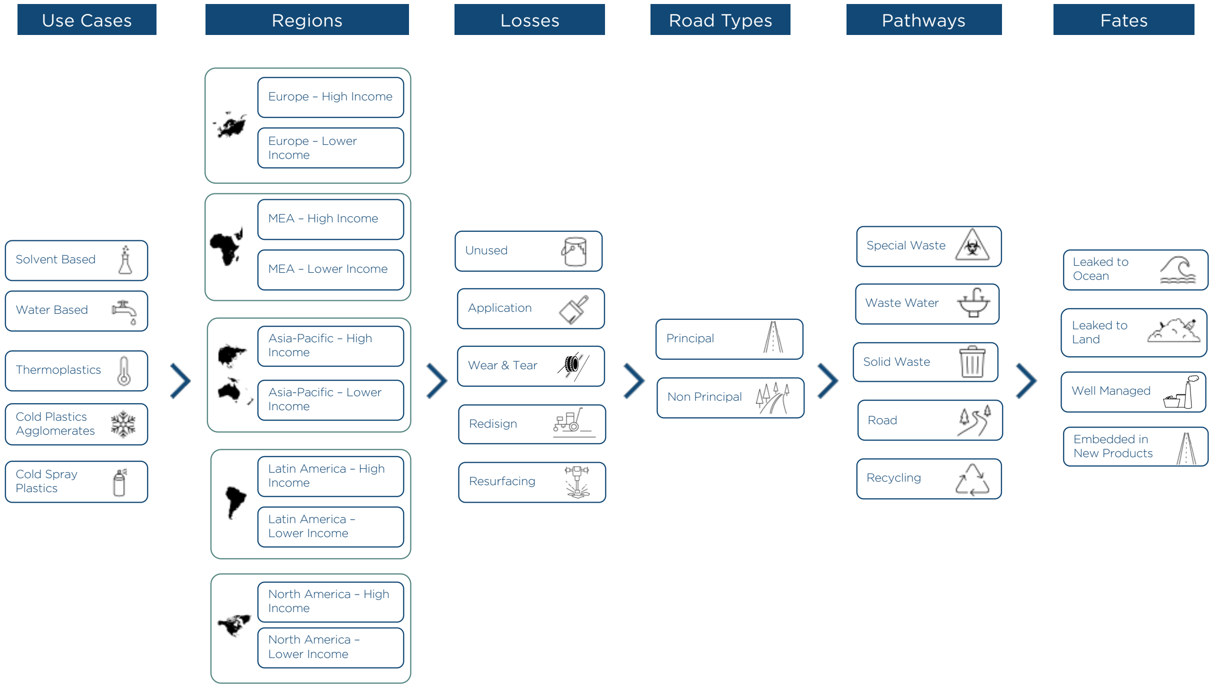
Global paint demand
1%

2%
Of global paint-related plastic pollution

234 kt
Of plastic used in production of Road Markings paint in 2019

173 kt
Plastic lost to Ocean & Waterways and Land due to Road Markings paint

PAINT FLOWS IN THE ROAD MARKINGS SECTOR



The system map, shows the stages/categories of the modelling process, from production to fate.

1. The first category "Paint type" shows the demand of Road Markings sector for different paint types: water based, solvent based, thermoplastics, cold plastics.

2. Different amount of paint for road markings are used around the globe, the analysis by "Regions" accounts for the geographical distribution of the paint uses and losses all over the globe.

3. The "Losses" category highlights whether paint is lost before reaching its supporting material (application, repainting), detaches from it (Wear & Tear, removal) is disposed with or without it (unused, EOL).

4. Paint can then find its way into several "Pathways", which represent where the paint is being discarded or stored.

5. Lastly, the "Fates" provide the distribution of the paint in the three main compartments: "leaked to Ocean & Waterways", "leaked to Land" and "well managed" or "embedded in new products" (i.e. paint embedded in recycled asphalt),

ROAD MARKINGS SECTOR PAINT FLOWS ACROSS CATEGORIES

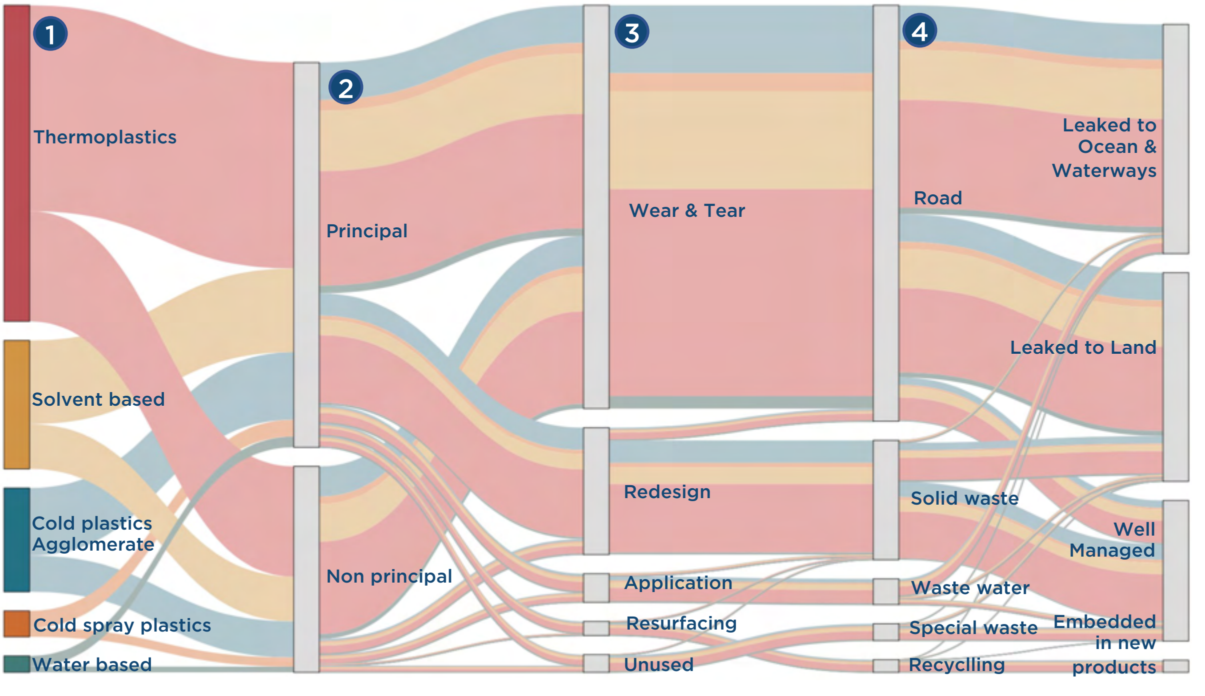
The Sankey diagram shows how road markings flows across various categories before reaching its final fate. The Regional analysis is performed in a dedicated section.

1

54% of the plastic used in the road markings paint sector is used in **Thermoplastics**. **Solvent based** paint and **Cold plastics** (including agglomerates substrate and spray) paint have 22% of the plastic share each, while water based paint has only 3%. Cold plastic paint is 35% plastic, while the other paint types are 16%-17% plastic.

2

Categorising the roads in **Principal** and **Non-Principal** allows to analyse different road maintenance patterns. Principal roads undergo more frequent paint jobs and tolerate lower Wear & Tear losses than Non-Principal roads. As a proxy for the principal / non-principal split, we use the urban vs rural share of the population in a region, leading to a 65% share of Principal roads.



3

68% of the paint will be undergo **Wear & Tear** during its lifetime, due to tyre abrasion and meteorological events. 21% will be **Removed**, mostly through grinding, when **redesigning** traffic lanes or parking lots.

4

The paint that is lost through Wear & Tear finishes in the **Road** runoff pathway, together with some of the paint that is removed during redesign. 2% of the paint will still be left on the road surface as it undergoes recycling (96% of asphalt is recycled in the EU to make new roads). We do not account the possible leakage from the paint embedded in recycled asphalt.

ROAD MARKINGS CONTRIBUTION TO PLASTIC LEAKAGE

In order to have information necessary to be able to tackle plastic pollution from Road Markings paint, it is useful to look at what are the highest contributors at each step of the system map.

Use cases

Thermoplastics paint is the top contributor to plastic pollution to the environment. This is due to thermoplastics being the most used type of paint for road markings. Thermoplastic has actually the lowest leakage rate, 73%, against Solvent based and Water based paints which have 78% leakage rate. This difference is explained by the fact that Thermoplastic paint is 3 to 4 times more durable than Solvent or Water based paint.

Leakage (kt)		Leakage rate (%)
Solvent Based	40	78%
Water Based	5	78%
Thermoplastics	91	73%
Cold Plastics Agglomerates	30	73%
Cold Spray Plastics	8	75%
Total (kt)	173	

Road types

Principal roads and non-principal roads are used to model two different maintenance scenarios. Principal roads undergo more frequent maintenance, i.e. smaller Wear & Tear losses allowed before repainting and more frequent resurfacing. A more frequent maintenance reduces the leakage rate from 87% (non-principal roads) to 68% (principal roads).

Leakage (kt)		Leakage rate (%)
Principal	103	68%
Non Principal	70	86%
Total (kt)	173	

Losses

Wear & Tear is the main cause of paint pollution (143 kt). On principal roads, repainting of road markings happens every 1-2 years for Water based and Solvent based paint and every 3-5 years for Thermoplastics paint, this is considered to correspond to 30% loss rate. On non-principal roads, a 70% loss rate is attained before repainting. Since resurfacing only happens every 20-30 years, Wear & Tear losses accumulate over time and account for 82% of the road markings leakage. Another 20 kt of plastic leakage is due to the mismanagement of the paint removed during redesing,.

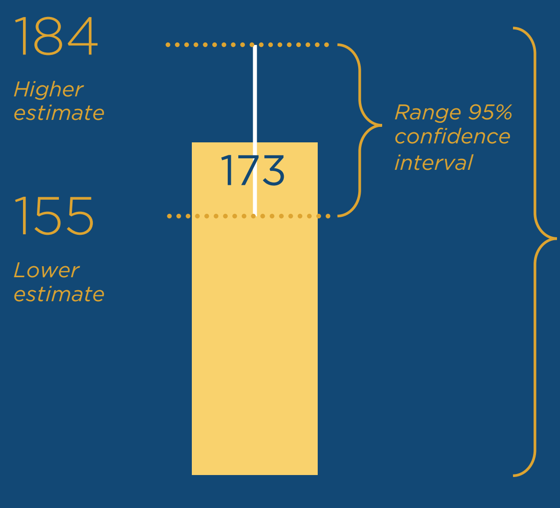
Leakage (kt)		Leakage rate (%)
Unused	1.4	21%
Application	9	77%
Wear & Tear	143	89%
Redisign	20	40%
Resurfacing	0.4	7%
Total (kt)	173	

Leakage (kt)		Leakage rate (%)
Special Waste	1	20%
Waste Water	8	81%
Solid Waste	16	35%
Road	147	89%
Recycling	0.2	4%
Total (kt)	173	

Pathways

147 kt of paint finds its way to the environment through Road runoff. Depending on the country, the Road runoff pathway can lead to losses to Soil, Ocean & Waterways or treatment in a waste water management facility There the paint will either be removed from the water or it will end up in Ocean & Waterways. According to our analysis (see General Appendix, Road pathway), only 11% of the paint that reaches the Road runoff pathway will be well managed, 50% will leak to Ocean & Waterways and 39% will leak to Land.

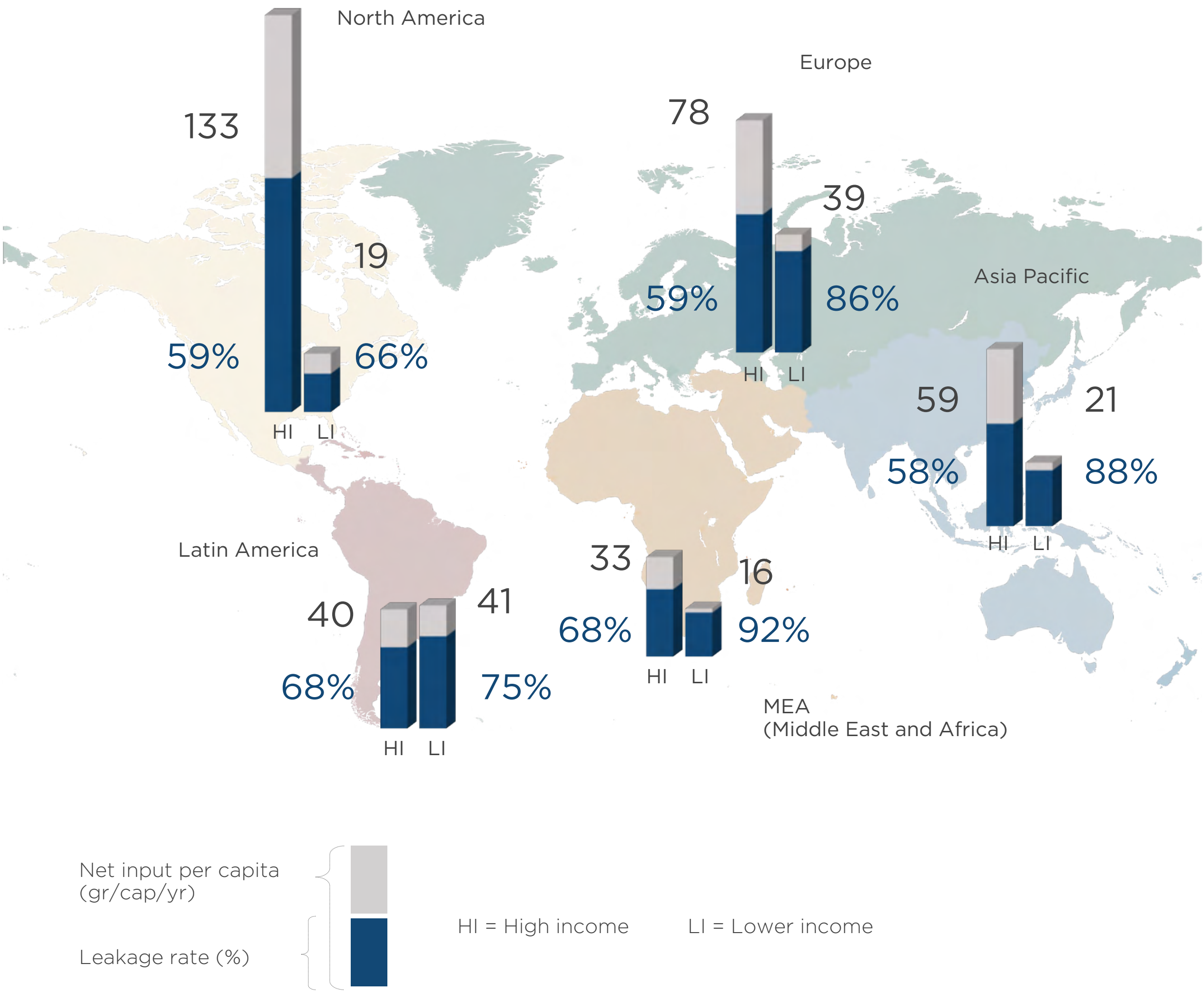
LEAKAGE

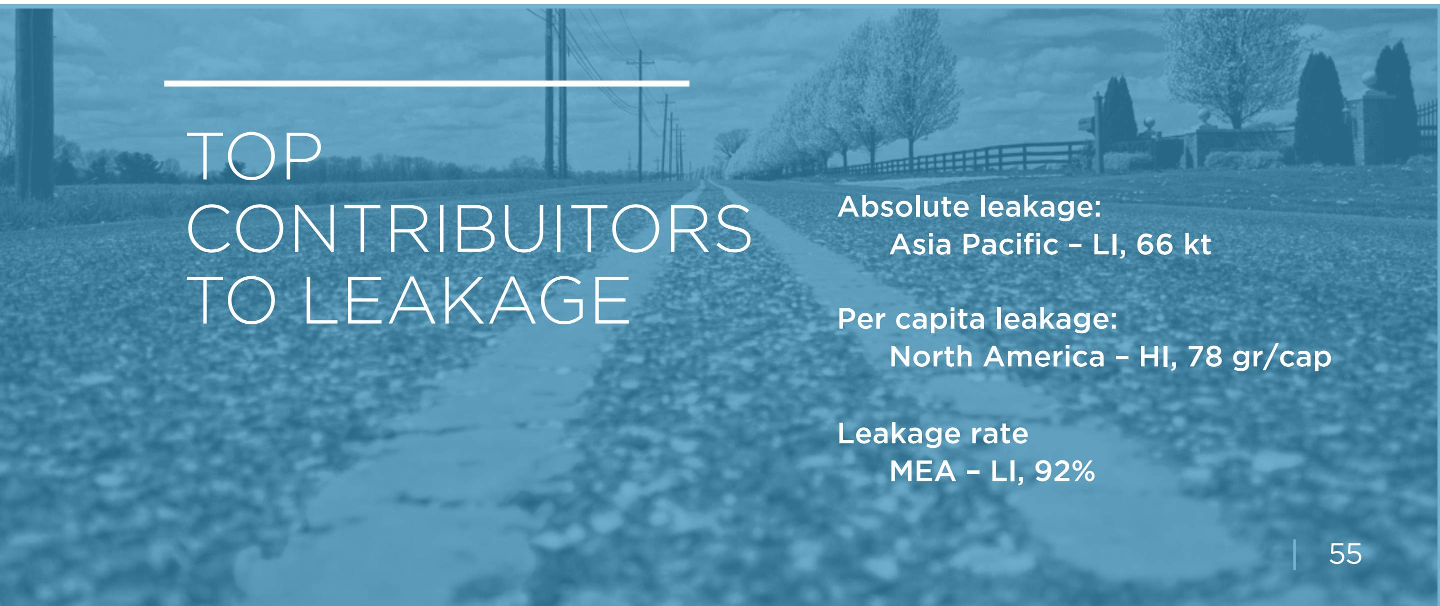


	Microplastic	Macroplastic	Σ
Ocean & Waterways	91	0	91
Land	81	2	83
Σ	172	2	

Values in kt

REGIONAL ANALYSIS OF LEAKAGE BY REGION





TOP CONTRIBUITORS TO LEAKAGE

Absolute leakage:
Asia Pacific – LI, 66 kt

Per capita leakage:
North America – HI, 78 gr/cap

Leakage rate
MEA – LI, 92%

REGIONAL ANALYSIS OF LEAKAGE BY REGION

1 |

The top three contributors of road marking plastic leakage are: Asia Pacific – Lower Income (66 kt) North America – High income (28 kt) Europe – High Income (23 kt).

2 |

In the model used for the analysis there are three main factors that influence the leakage by region:

- The paint demand by country, estimated based on the kilometres of road in the country.
- The frequency at which re-painting happens. Principal road undergo more frequent re-painting and lower Wear & Tear rates than non-principal roads.
- The treatment of road runoff water by country.

3 |

The leakage rates vary between regions from 59% in North America – High income to 93% in MEA – Lower income. Nonetheless, since the road-network and consequently the paint consumption varies greatly from country to country, the highest per capita leakage of paint is observed in North America – High income countries, with 78 gr/cap against the world average of 13 gr/cap.

WHAT IS THE RANGE OF LEAKAGE RATES?

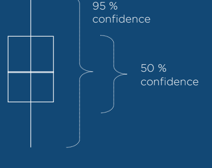
Between 59% in North America - HI and 93% in MEA – Lower Income

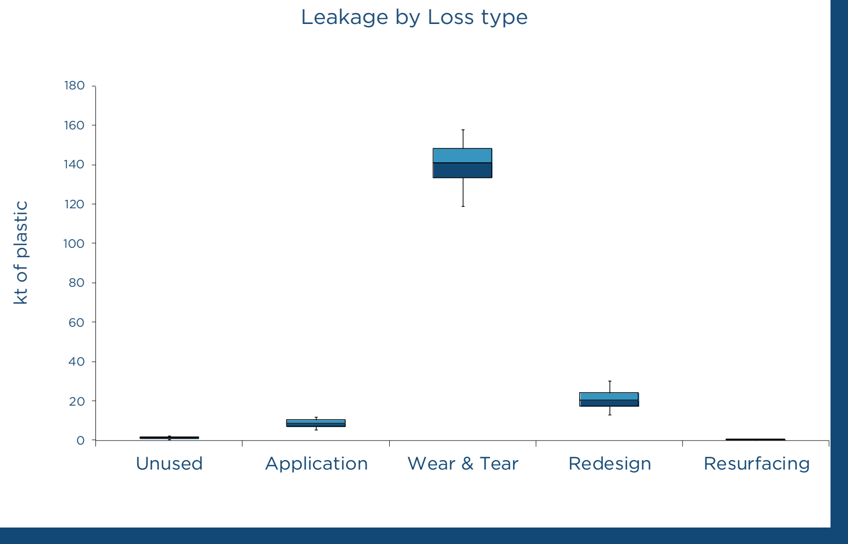
SENSITIVITY ANALYSIS

Modelling the amount of leakage coming from road markings paint required various modelling assumptions. A sensitivity analysis, using Monte Carlo simulations, was performed to test a range of uncertainty of most of the modelling steps and assess the impact on the results. The box plot shows the plastic leakage for the different loss types.

Leakage of Road Markings paint to the environment is estimated to be in the rage:

- 170 kt – 179 kt 50% confidence interval.
- 158 kt - 187 kt 95% confidence interval.





The uncertainty range of road marking paint is small, with only a +/- 3% for the 50% confidence interval and a +/- 9% for the 95% confidence interval. The main reason behind this is that the Wear & Tear-repaint cycle is much shorter than the lifetime of the road (time between resurfacing): 1-4 years against 20-30 years, and that a large portion of the paint weathers at each Wear & Tear cycle (30% to 70%). As a result, over time the paint applied weathers almost completely, with only a fraction of the paint being removed when there is a need to redesign traffic lanes.

Limitations of the study

The only road marking paint that is applied to the road and ends up being well managed, is paint that is removed due to redesigning or paint that reaches the Waterways runoff and it is then filtered in waste water treatment facility and subsequently incinerated. Therefore to improve the assessment of Road markings paint leakage, it is important to focus of correctly quantifying these

GENERAL INDUSTRIAL

PAINT USE IN GENERAL INDUSTRIAL AND ITS IMPACT

General industrial paint accounts for 15% of the global paint demand, amounting to 7.7 Mt.

In 2019, 2'915 kt of plastic were used to make paint for the general industrial sector.

60% of the total paint used in the general industrial sector will eventually end up in the environment, including 1'744 kt of plastic. Of this plastic, 877 kt will leak to Ocean & Waterways. 76% of the total leakage will be in the form of microplastic.

In terms of share of paint-related plastic pollution this represents 24% of the global amount.

Global paint demand

15%

24%

Of global paint-related plastic pollution

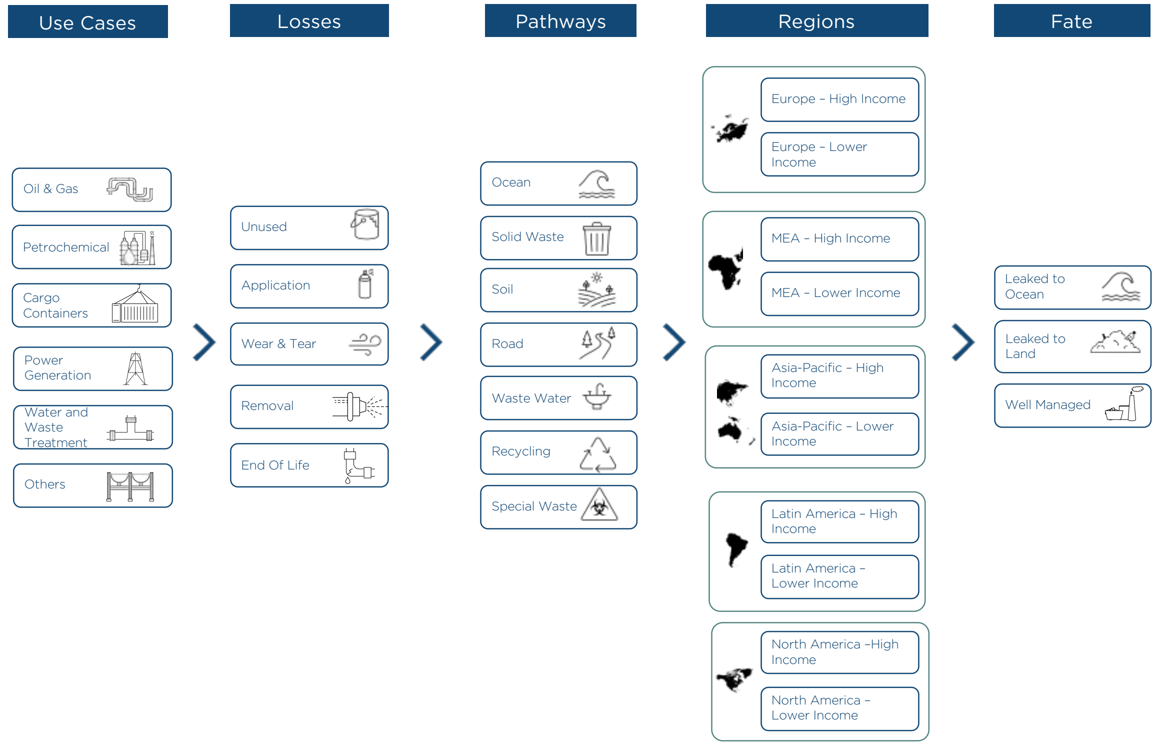
2'915 kt

Of plastic used in production of General Industrial paint in 2019

1'744 kt

Plastic lost to the Ocean & Waterways and Land due to the General Industrial paint sector

PAINT FLOWS IN THE GENERAL INDUSTRIAL SECTOR



The system map, shows the stages/categories of the modelling process, from production to fate.

1. The first category "Use cases" shows the demand of general industrial paint by sub-sector: Oil & Gas, Petrochemical, Cargo containers, Power generation, Water and waste water treatment, and others.

2. The analysis by "Regions" accounts for the geographical distribution of the paint uses and losses around the world.

3. The "Losses" category highlights whether paint is lost before reaching its supporting material (application, repainting), detaches from it (Wear & Tear, removal) is disposed with or without it (unused, EOL).

4. Paint can then find its way into several "Pathways", which represent where the paint is being discarded or lost. Often general industrial paint is applied on metal, the "recycling" pathways refers to the recycling of metal.

5. Lastly, the "Fates" provide the distribution of the paint in the three main compartments: "leaked to Ocean & Waterways", "leaked to Land", "well managed" and "embedded in new products" together with the original supporting material.

GENERAL INDUSTRIAL SECTOR PAINT FLOWS ACROSS CATEGORIES

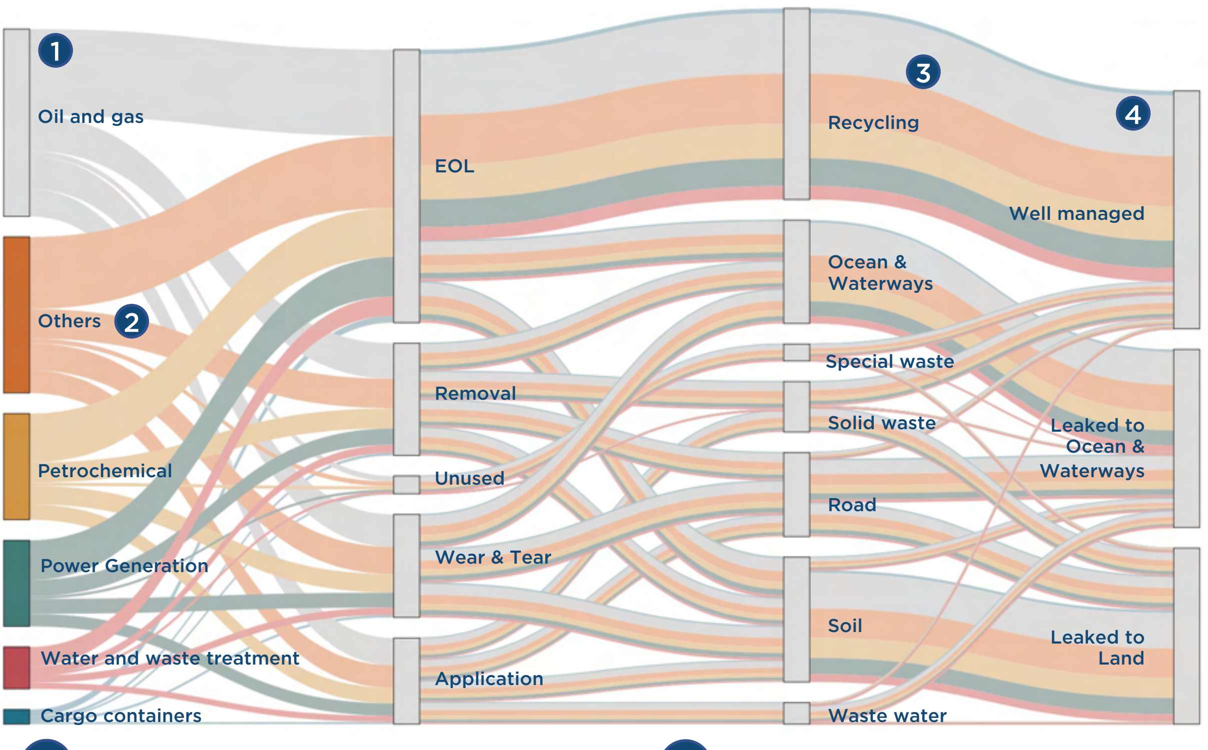
The Sankey diagram shows how General Industrial sector paint flows across various categories before reaching its final fate. The Regional analysis is performed in a dedicated section.

1

32% of the paint is used by the **Oil & Gas sector** (refineries, pipelines, offshores), 18% is used by the petrochemical sector, 15% on power generation applications.

2

26% of the general industrial paint is applied on **other applications**, such as: steel bridges, coffee tables, powder-coated file drawers, computer cabinets, laptop computers, and cell phones, electronic components, bathroom scales, mailboxes, satellite dishes, toolboxes, fire extinguishers among various others.



3

Most of general industrial paint consists of protective coating applied to metal surfaces. We make the assumption that **70%** of the paint that is **left on the metal at its EOL**, will be dealt with at a recycling facility and properly disposed of.

4

1238 kt of plastic is **estimated to leak to Ocean & Waterways** from the general industrial sector and **519 kt** is estimated to **leak to Land.**

GENERAL INDUSTRIAL CONTRIBUTION TO PLASTIC LEAKAGE

Tracking plastic pollution from paint used in the General Industrial sector is made challenging because of data scarcity surrounding the different industrial sectors and their practices related to paint management.

Use cases

General industrial paint mostly consists in protective coatings used to prevent corrosion of metal surfaces. The Oil & Gas industry for example uses it to protect offshore installations, tanks and pipes in refineries as well as transport pipelines.

Leakage (kt)		Leakage rate (%)
Oil&Gas	552	30%
Petrochemical	313	30%
Cargo Containers	43	30%
Power Generation	253	30%
Water and Waste Treatment	123	30%
Others	459	30%
Total (kt)	1744	

Losses

Leakage (kt)		Leakage rate (%)
Unused	24	27%
Application	348	82%
Wear & Tear	494	97%
Removal	475	86%
EOL	403	30%
Total (kt)	1744	

In industrial environments corrosion of the paint system happens faster than in urban or rural environments (*KTA, 2017*). Based on loss rates, repaint intervals and object lifetime we estimated that 28% of the paint will be lost due to Wear & Tear. 27% is then lost during removal of paint for surface preparation. Surface preparation is essential to guarantee the quality of the paint job, and in the case of general industrial paint, it often happens through open grit blasting or high pressure water blasting, with large dispersion of paint particles into the environment.

Since general industrial application are often outdoor, sometimes close to Ocean or Waterways (offshore installations, bridges, cargo containers, underwater pipelines), they are more likely to lead to leakage to the environment.

Pathways

We estimate that 509 kt of plastic from General Industrial paint will leak directly into Ocean & Waterways, 615 kt will first leak to Soil (for example in the case of underground pipelines Wear & Tear or Removal), and 381 kt will leak to Road runoff.

	Leakage (kt)	Leakage rate (%)
Ocean	509	100%
Soil	615	100%
Road	381	92%
Solid Waste	128	51%
Waste Water	90	85%
Special Waste	21	26%
Recycling	0	0%
Total (kt)	1744	

LEAKAGE

2'154 *Higher estimate*

1'744

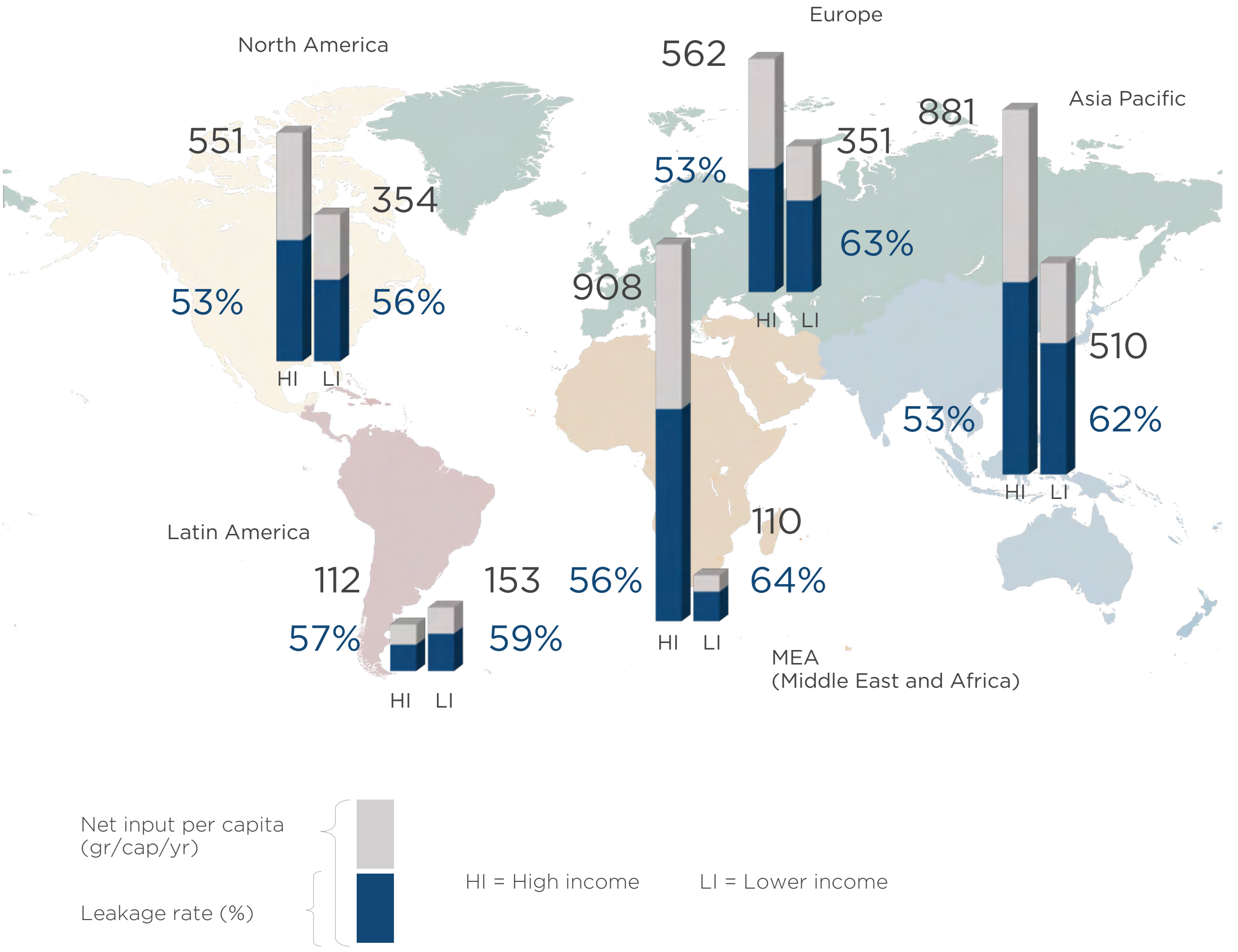
1'050 *Lower estimate*

Range 95% confidence interval

	Microplastic	*Macroplastic*	
Ocean & Waterways	653	224	877
Land	664	203	867
Σ	1317	427	

Values in kt

REGIONAL ANALYSIS OF LEAKAGE BY REGION



TOP CONTRIBUITORS TO LEAKAGE

Absolute leakage:
Asia Pacific – LI, 1’113 kt

Per capita leakage:
MEA – HI, 511 gr/cap/yr

Leakage rate
MEA – LI, 64%

REGIONAL ANALYSIS OF LEAKAGE BY REGION

1 |

The general industrial paint distribution by region is proportional to the region's demand of steel (by weight), based on the assumption that steel is the main support on which the paint is applied. Based on this 61% of the general industrial paint is used in Asia – Pacific – Lower income countries, which contribute to 64% of the total leakage.

2 |

Using the demand of steel sold as a proxy for the demand of paint, neglects the existing infrastructure. It is possible that countries with an already developed infrastructure will not have high consumption of new steel, but will have high consumption of paint used to maintain the infrastructure.

3 |

In this assessment the leakage of paint by region is almost entirely explained by the paint demand, as we did not assume that different regions or countries will have different application or removal practices. Nonetheless, management of Solid waste, Waste water, Special waste and Road-runoff are still country specific and impact the leakage rate. The highest leakage rate is associated with MEA – Lower income countries (64%) and the lowest one is in the High income regions of North America, Europe and Asia Pacific (53%).

LOWEST AND HIGHEST LEAKAGE RATES

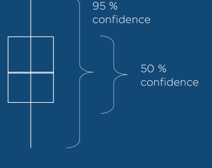
Europe - HI, North America– HI, and Asia Pacific – HI at 53%
MEA – Lower Income – 64%

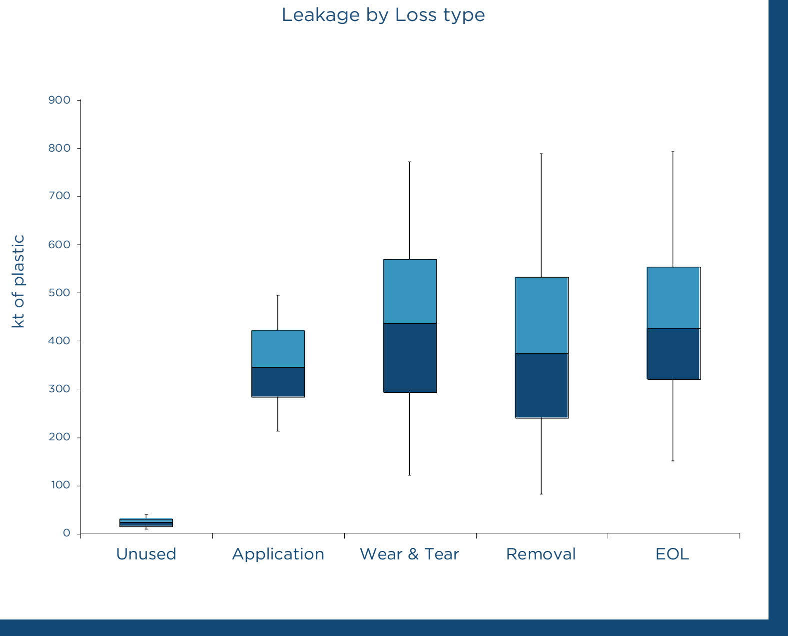
SENSITIVITY ANALYSIS

Modelling the amount of leakage coming from general industrial paint required various modelling assumptions. A sensitivity analysis, using Monte Carlo simulations, was performed to test a range of uncertainty of most of the modelling steps and assess the impact on the results. The box plot shows the plastic leakage for the different loss types of general industrial paint.

Leakage of general industrial paint to the environment is estimated to be in the rage:

- 1.5 Mt - 1.8 Mt 50% confidence interval.
- 1.1 Mt – 2.2 Mt 95% confidence interval.





As visible from the graphs, the confidence interval of leakage contribution of Wear & Tear, removal and EOL are wide, but the overall confidence interval range is not the sum of the three.

A redistribution of losses from Wear & Tear to Removal for example will have little impact on the overall leakage, since their leakage rates are 97% and 86%, respectively.

In the end the confidence interval of the overall leakage of general industrial paint is most closely linked to the confidence interval of the share of paint that will be on the object at its EOL.

Limitations of the study

Many aspects surrounding paint practices by the general industrial sectors are undocumented and were modelled with high uncertainties. It would be crucial to know what is the paint distribution within sub-sector by regions. How much of the paint is destined to structures that are close to aquatic environments (e.g. offshores, underwater pipelines, bridges)?

The maintenance frequency and general practices are also not clear.

General industrial is definitely the sector where data are the scarcest.

AUTOMOTIVE

PAINT USE IN AUTOMOTIVE AND ITS IMPACT

Automotive paint accounts for 10% of the global paint demand, amounting to 5.5 Mt.

In 2019, 2'041 kt of plastic were used to make paint for the automotive sector.

28% of the total paint used in the automotive sector will eventually end up in the environment, including 576 kt of plastic. Of this plastic, 66 kt will leak to Ocean & Waterways.
76% of the total leakage will be in the form of microplastic.
37% of the total leakage will be in the form of microplastic.

In terms of share of paint-related plastic pollution this represent 8% of the global amount.

Global paint demand

10%

8%

Of global paint-related plastic pollution

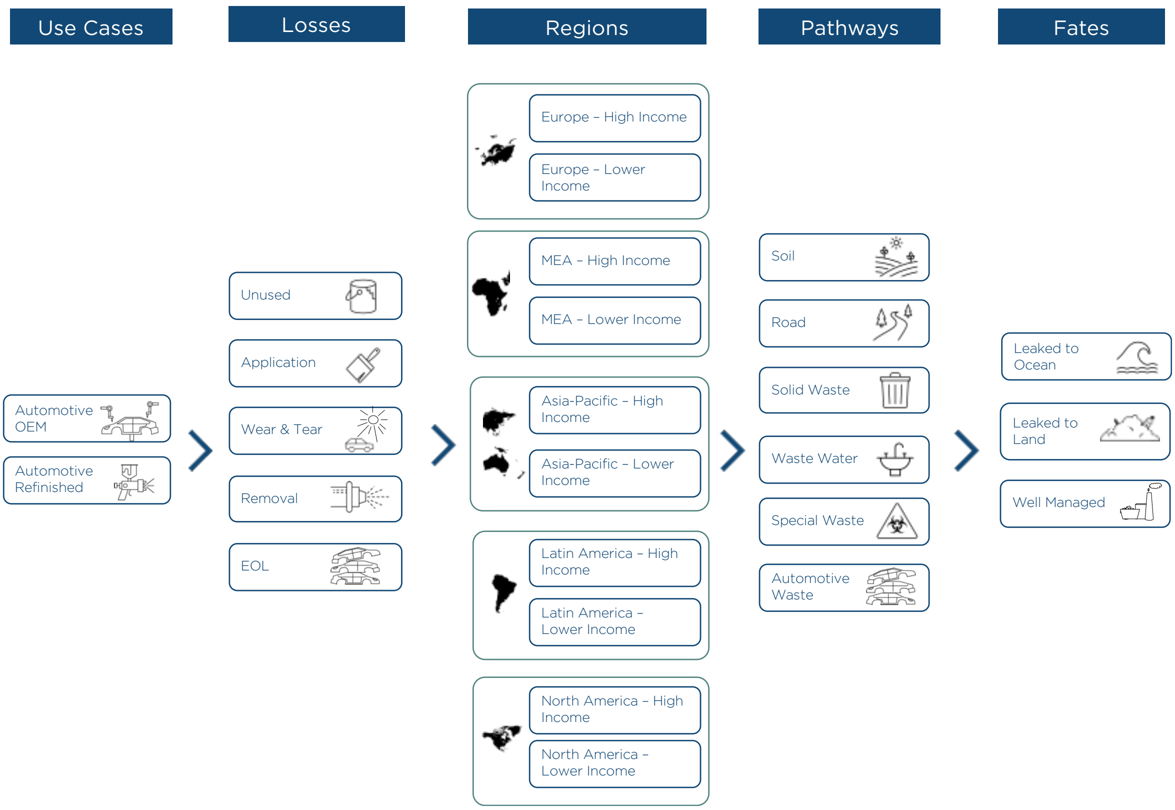
2'041 kt

Of plastic used in production of Automotive paint in 2019

576 kt

Plastic lost to the Ocean & Waterways and Land due to Automotive paint

PAINT FLOWS IN AUTOMOTIVE



The system map, shows the stages/categories of the modelling process, from production to fate.

1. The first category "Use cases" refers to paint applied during the manufacturing process (Original Equipment Manufacturer) or in bodyshop for maintenance (refinish).

2. The analysis by "Regions" accounts for the geographical distribution of the paint uses and losses around the world.

3. The "Losses" category highlights whether paint is lost before reaching its supporting material (application, repainting), detaches from it (Wear & Tear, removal) is disposed with or without it (unused, EOL).

4. Paint can then find its way into several "Pathways", which represent where the paint is being discarded or lost. "Automotive waste" is a pathway specific to the automotive sector and it designates the disposal of cars that reach the EOL.

5. Lastly, the "Fates" provide the distribution of the paint in the three main compartments: "leaked to Ocean & Waterways", "leaked to Land", "well managed".

AUTOMOTIVE SECTOR PAINT FLOWS ACROSS CATEGORIES

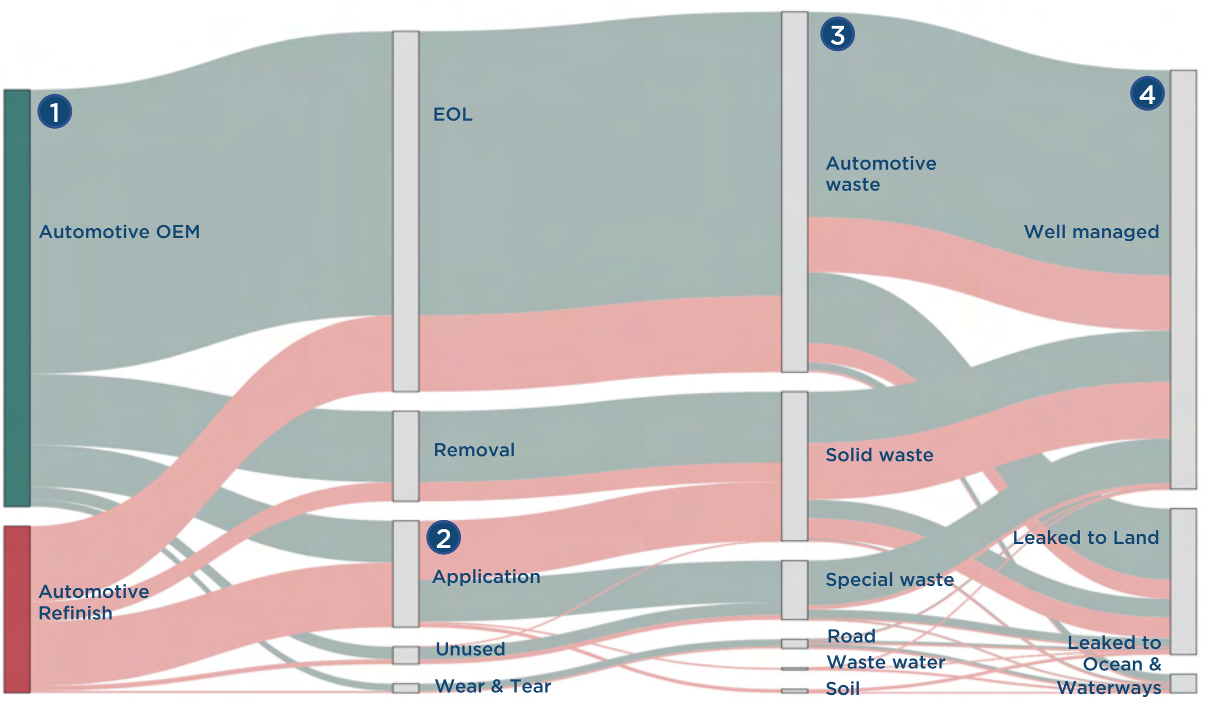
The Sankey diagram shows how automotive paint flows across various categories before reaching its final fate. The Regional analysis is performed in a dedicated section.

1

71% of the paint is used for automotive **OEM**, applied during the car manufacturing process, and 29% for automotive Refinish, appied at a later stage for example due to an accident, a damage to the original paint system or to change the car color.

2

Automotive paint is applied by spray. *OECD, 2009* analysis proposes a 35% loss rate at **Application** for OEM and a 66% loss rate for Refinish. In this analysis more conservative estimates of **10% and 40% loss rates** were used (see Automotive appendix).



3

92% of the automotive paint put on the market is **disposed through a waste pathway**: Automotive waste (62%), Solid waste (26%), Special waste (10%) and Waste water (0.3%). Only losses due to Wear & Tear happen in an uncontrolled environment and go through the Road runoff pathway.

4

74% of the automotive paint is well managed, 23% leaks to Land (mainly from waste mismanagement), and 3% leaks to Ocean & Waterways (mainly from Road runoff).

AUTOMOTIVE PAINT CONTRIBUTION TO PLASTIC LEAKAGE

In order to have information necessary to be able to tackle plastic pollution from Automotive paint, it is useful to look at what are the highest contributors at each step of the system map.

Use cases

400 kt of automotive OEM and 176 kt of Refinish paint leak to the environment. Altought the leakage rates for the two types of paint are very similar (27% for OEM and 30% for Refinish), the processes leading to the leakage are different. In the case of OEM they are linked to mismanagement of removed paint in the body shop, while in the case of Refinish they are linked to losses at Application in the body shop. Ultimaltely though the majority of the leakage is linked to the automotive EOL, for both types of paint.

	Leakage (kt)	Leakage rate (%)
Automotive OEM	400	27%
Automotive Refinish	176	30%
Total (kt)	576	

	Leakage (kt)	Leakage rate (%)
Unused	10	17%
Application	100	27%
Wear & Tear	28	87%
Removal	88	28%
EOL	350	28%
Total (kt)	576	

Losses

Since automotive paint is applied with spray guns, the losses at application are high compared to sectors where application is done by brush or roller. On the other hand, these losses happen in a controlled environment and can more easily be collected, unlike for example exterior architectural paint. Nonetheless, since mismanagement of waste is widespread in many countries, overall 27% of the paint loss at application leaks to the environment, for a total of 100 kt.

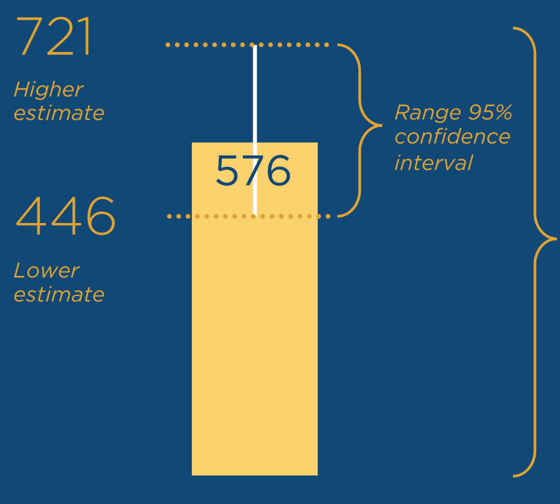
The highest leakage contribution comes from EOL losses with 350 kt of leakage and a 28% leakage rate, once again linked to waste mismanagement.

Pathways

Most of the leakage (350 kt) comes from Automotive waste pathway linked to car EOL disposal, 145 kt come from Solid waste pathway (mostly from application and removal losses) and 28 kt come from Road runoff pathways (from Wear & Tear). Here we include in the Wear & Tear losses flaking and chipping of car paint that can be due to weather (such as exposure to ultra-violet sun rays), but also to accidents and collisions.

Pathway	Leakage (kt)	Leakage rate (%)
Soil	13	100%
Road	28	87%
Solid Waste	145	28%
Waste Water	5	77%
Special Waste	35	17%
Automotive Waste	350	28%
Total (kt)	576	

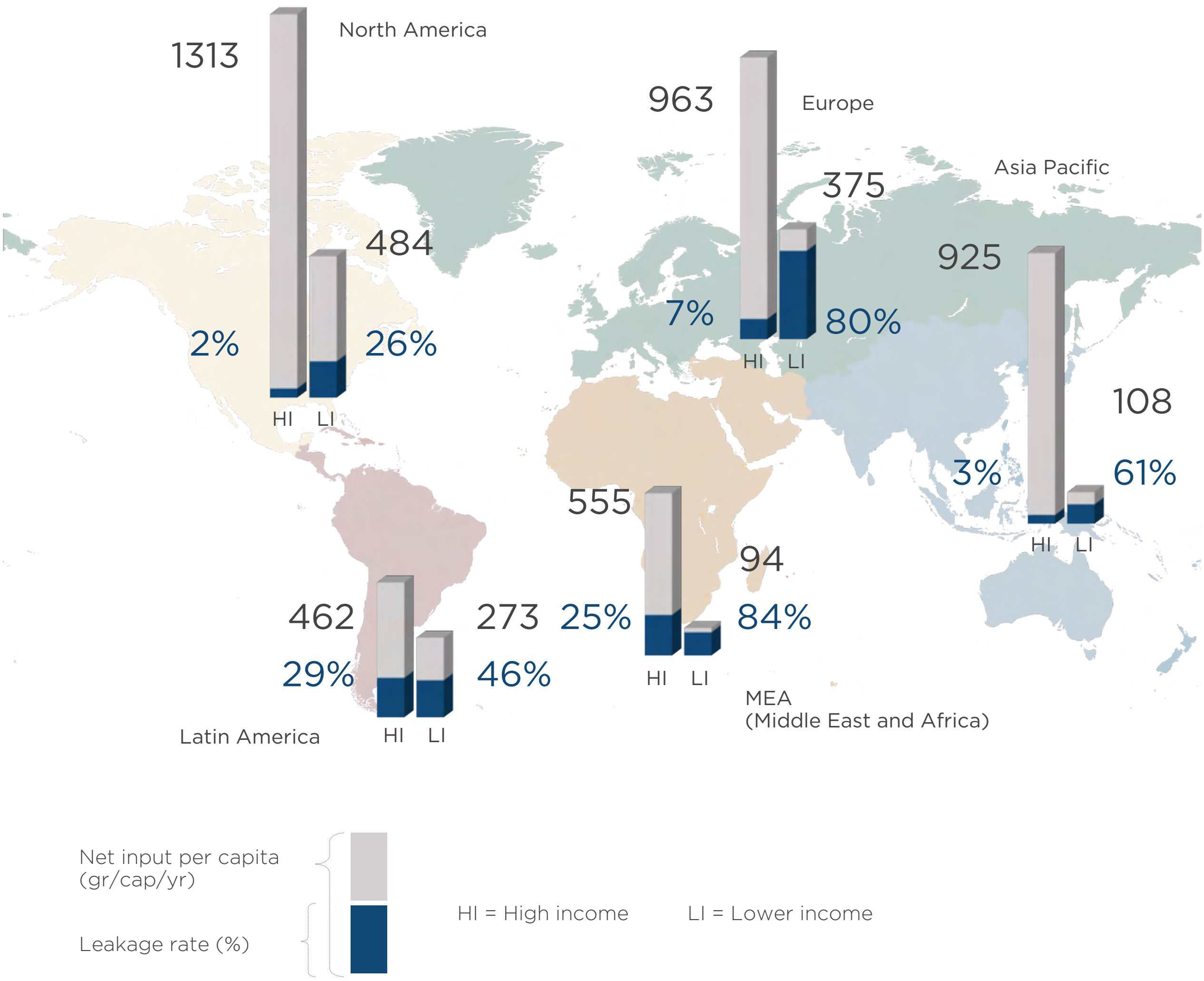
LEAKAGE



	Microplastic	Macroplastic	
Ocean & Waterways	30	36	66
Land	86	324	511
Σ	216	360	

Values in kt

REGIONAL ANALYSIS OF LEAKAGE BY REGION



TOP CONTRIBUITORS TO LEAKAGE

Absolute leakage:
Asia Pacific – LI, 1'263 kt

Per capita leakage:
Europe – LI, 329 gr/cap

Leakage rate
MEA – LI, 87%

REGIONAL ANALYSIS OF LEAKAGE BY REGION

1 |

The distribution of the automotive paint by region is modelled by taking into account: the number of vehicles manufactured by country (used to allocate the Automotive OEM paint losses at Application or Unused), and the number of vehicles in use per country (used to allocate all other losses). Ultimately since the OEM losses at Application and Unused are small, the distribution by region is mostly mirroring the number of vehicles by country.

2 |

The highest contribution to the leakage comes from Asia Pacific - Lower income countries with 231 kt of absolute leakage, or 40% of the total leakage. The per capita paint demand and leakage of the region, though, are below average. This is mostly because the number of vehicles per capita is the lowest in the world.

3 |

There is a striking difference between the per capita paint demand of High income and Lower income countries. With the exception of Europe – Lower income countries, the demand is on average 3.5 times higher in High income regions. On the other hand the leakage rate is on average 13% in HI and 60% in LI, since it is in large part due to mismanagement of waste.

4 |

Europe – Lower Income is an exception because the it has a per capita paint demand similar to that of High income regions, couple with one of the worst leakage rates (80%). As a result Europe - LI has by far the highest per capita leakage with 301 gr/cap/yr, against the world average of 83 gr/cap/yr.

LOWEST AND HIGHEST LEAKAGE RATES

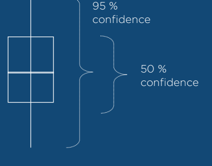
North America – High Income – 2.3%
MEA – Lower Income – 84%

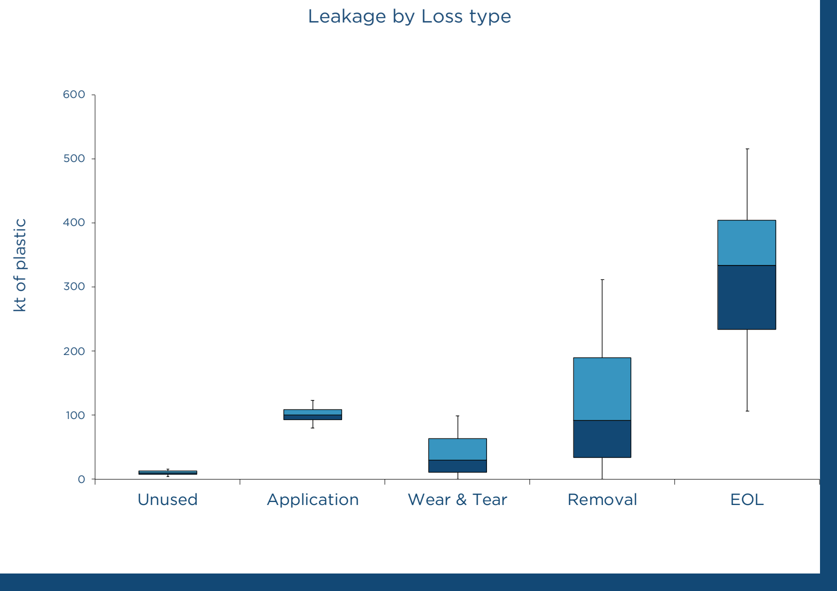
SENSITIVITY ANALYSIS

Modelling the amount of leakage coming from automotive paint required various modelling assumptions. A sensitivity analysis, using Monte Carlo simulations, was performed to test a range of uncertainty of most of the modelling steps and assess the impact on the results. The box plot shows the plastic leakage for the different loss types of automotive paint.

Leakage of automotive paint to the environment is estimated to be in the rage:

- 538 kt – 631 kt 50% confidence interval.
- 446 kt - 721 kt 95% confidence interval.





The small range of the confidence interval of automotive paint leakage is due to the fact that Automotive waste, Special waste and Solid waste pathways, which channel 86% of all automotive paint, are modelled in a similar way. This is a limitation of the model, due to the fact that we did not perform an analysis on the fate of automotive vehicles, on recycling or re-use practices. This would be needed to have a better understanding of the probable fates of paint from the "Automotive waste" pathway. In this analysis, fates of Solid waste are used to determine the fates of Automotive waste.

Limitations of the study

The fate of vehicles when they are discarded is the greatest uncertainty of the model.

INDUSTRIAL WOOD

PAINT USE IN INDUSTRIAL WOOD AND ITS IMPACT

Industrial wood paint accounts for 6% of the global paint demand, amounting to 3.3 Mt.

In 2019, 1'232 kt of plastic were used to make paint for the industrial wood sector.

36% of the total paint used in the industrial wood sector will eventually end up in the environment, including 439 kt of plastic. Of this plastic, 33 kt will leak to Ocean & Waterways.
56% of the total leakage will be in the form of microplastic.

In terms of share of paint-related plastic pollution this represent 6% of the global amount.

Global paint demand

6%

6%

Of global paint-related plastic pollution

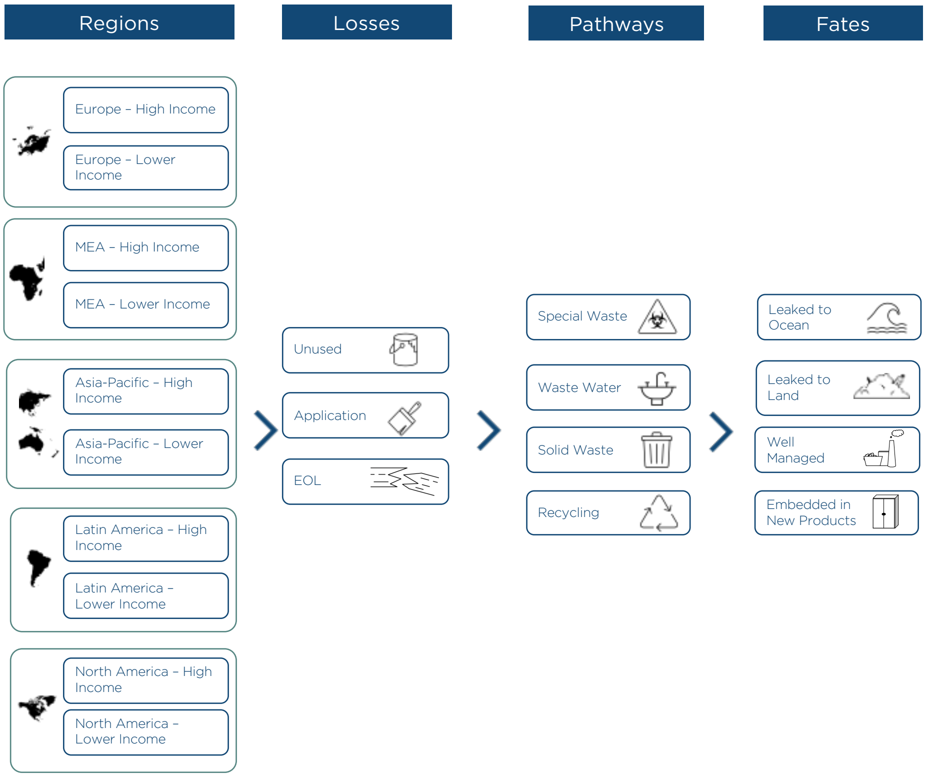
1'232 kt

Of plastic used in production of Industrial Wood paint in 2019

439 kt

Plastic lost to the Ocean & Waterways and Land due to the Industrial Wood paint

PAINT FLOWS IN INDUSTRIAL WOOD



The system map, shows the stages/categories of the modelling process, from production to fate.

1. We did not differenciate between the dirrent possible application of industrial wood paint. It is typically applied on wooden surfaces such as "joinery, kitchen cabinets, furniture, flooring, millwork, specialty wood products, and exterior building products" (American Coatings Association, 2018)

2. The analysis by "Regions" accounts for the geographical distribution of the paint uses and losses around the world.

3. The "Losses" category includes only losses due to application or to disposal of unused paint or paint left on the object at its EOL.

4. Paint can then find its way into several "Pathways", which represent where the paint is being discarded or lost.

5. Lastly, the "Fates" provide the distribution of the paint in the three main compartments: "leaked to Ocean & Waterways", "leaked to Land", "well managed" and "embedded in new products" (such as plywood and particle board).

INDUSTRIAL WOOD SECTOR PAINT FLOWS ACROSS CATEGORIES

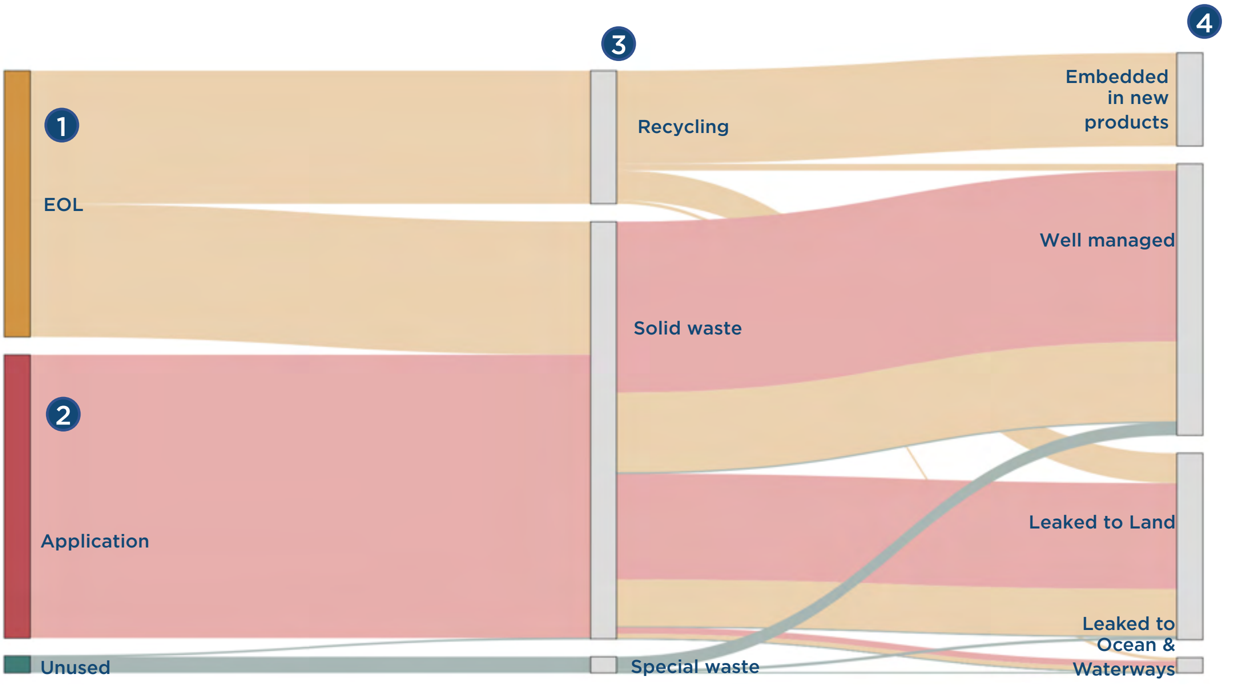
The Sankey diagram shows how industrial wood paint flows across various categories before reaching its final fate. The Regional analysis is performed in a dedicated section.

1

According to *OECD, 2009* industrial wood coatings can be applied in various way: dry booth, wet booth, curtain coating, etc. In this study we assume for simplicity that only the dry booth technique is applied. Losses at application are estimated to be 52% (*OECD, 2009*). We assume that most wooden applications will be used indoor, and that the Wear & Tear losses are negligible.

2

Painted or varnished wood is sometimes considered recyclable in order to produce wood chippings, while in other contexts regulation asks for painted wood to be disposed of as waste. We assume that of the paint that is left on the wood until its end of life, **50% will follow the wood during its recycling process and the other 50% will be disposed as waste**.



3

74% of the paint is disposed as **Solid waste**, 3% as Special waste, and 23% goes through wood Recycling process.

4

Ultimately, **48%** of the paint will be **well managed** (mostly due to the proper management of overspray losses at application), 16% be embedded in new products and 36% will leak to the environment.

INDUSTRIAL WOOD PAINT CONTRIBUTION TO PLASTIC LEAKAGE

In order to have information necessary to be able to tackle plastic pollution from Industrial Wood paint, it is useful to look at what are the highest contributors at each step of the system map.

Losses

244 kt of plastic leakage come from overspray losses at application. The losses happen in a controlled environment, and are only caused by waste mismanagement. Similarly, 187 kt of leakage are linked to mismanagement of waste at EOL.

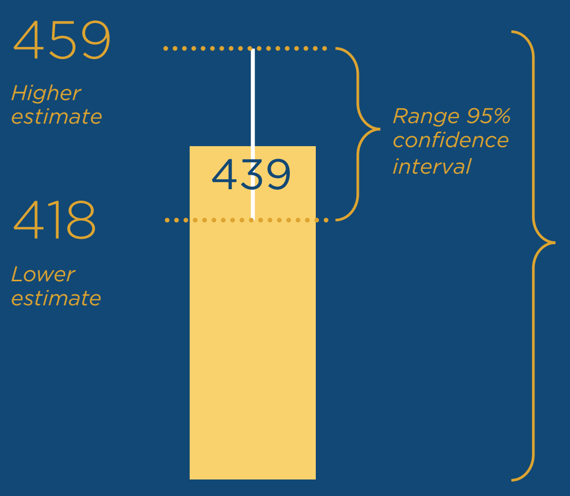
	Leakage (kt)	Leakage rate (%)
Unused	8	21%
Application	244	40%
EOL	187	32%
Total (kt)	439	

Pathways

	Leakage (kt)	Leakage rate (%)
Special Waste	7	20%
Solid Waste	360	40%
Recycling	72	25%
Total (kt)	439	

40% of the paint that is disposed as solid waste leaks to the environment, for a total of 360 kt of leakage. This is due to mismanagement of paint dust generated by overspraying but also mismanagement of painted wood. No literature could be found on paint losses during the recycling of coated wood, but there is evidence that recycling involves breaking and grinding processes, sometimes conducted outdoor, which leads to dust formation and dispersion in the surrounding environment.

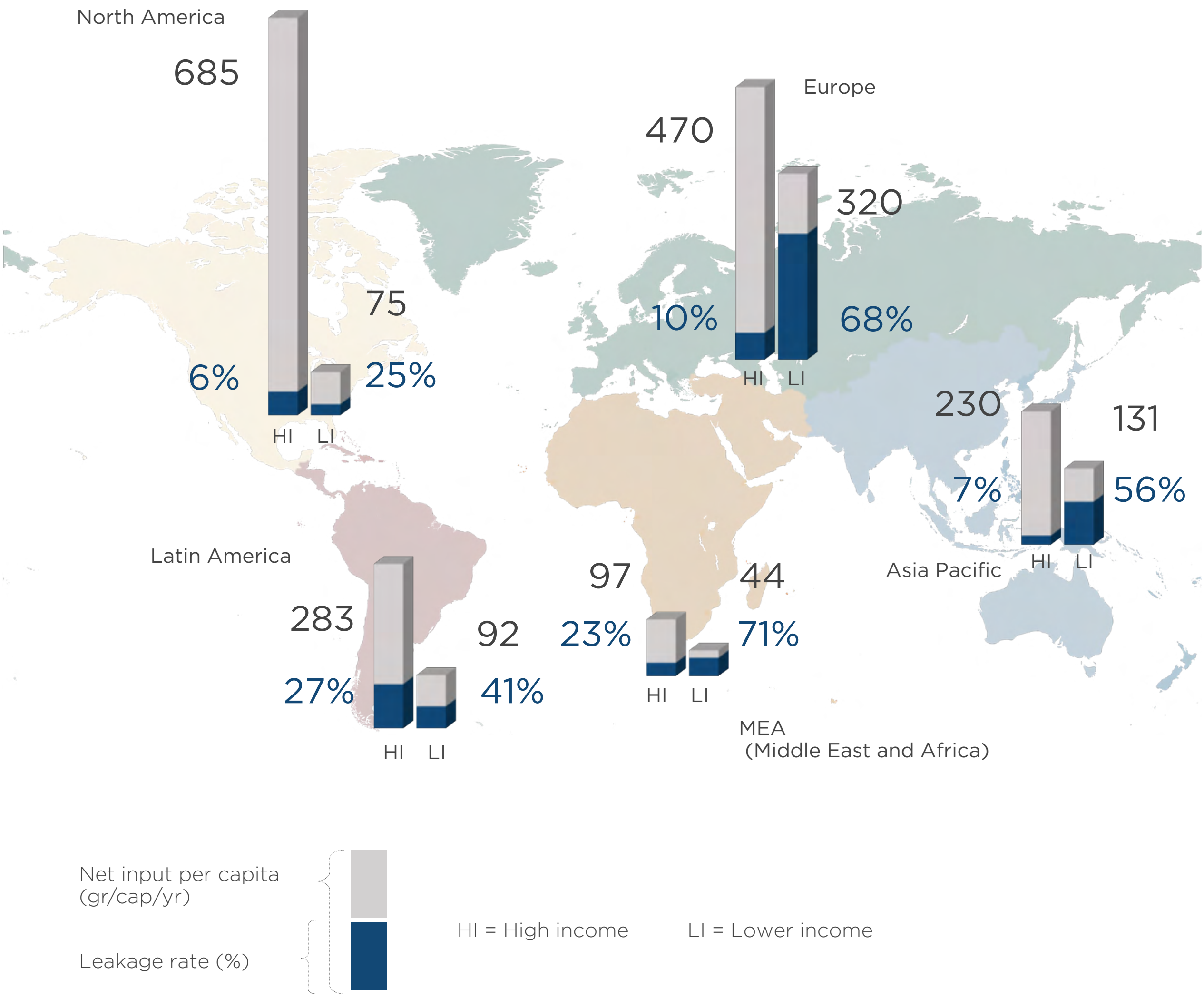
LEAKAGE



	Microplastic	Macroplastic	
Ocean & Waterways	14	19	33
Land	230	175	406
Σ	244	195	

Values in kt

REGIONAL ANALYSIS OF LEAKAGE BY REGION



TOP CONTRIBUITORS TO LEAKAGE

Absolute leakage:
Asia Pacific – LI, 259 kt

Per capita leakage:
Europe – LI, 217 gr/cap

Leakage rate
MEA – LI, 71%

REGIONAL ANALYSIS OF LEAKAGE BY REGION

1 |

The shares by regions are determined based on the wood consumption by country of products for selected wooden products: hardboard, MDF/HDF, OSB, other fibreboard, particle board, plywood, sawn wood, veneer sheets.

2 |

The highest contributor to leakage of industrial wood paint is the Asia Pacific – Lower income region, with 259 kt. The region accounts for 37% of the world consumption, but 59% of the world leakage.

3 |

When leakage is closely linked to waste mismanagement, often lower income countries present overall higher leakage rates. Lower income countries altogether account for 55% of the paint consumption and 89% of the leakage.

4 |

The highest per capita leakage is by far in Europe – Lower income region with 217 gr/cap against an average of 63 gr/cap across all regions. This is due to both high per capita consumption and high mismanagement rate of waste.

LOWEST AND HIGHEST LEAKAGE RATES

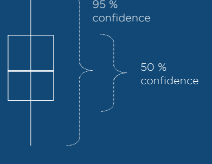
North America – High Income – 6%
MEA – Lower Income – 71%

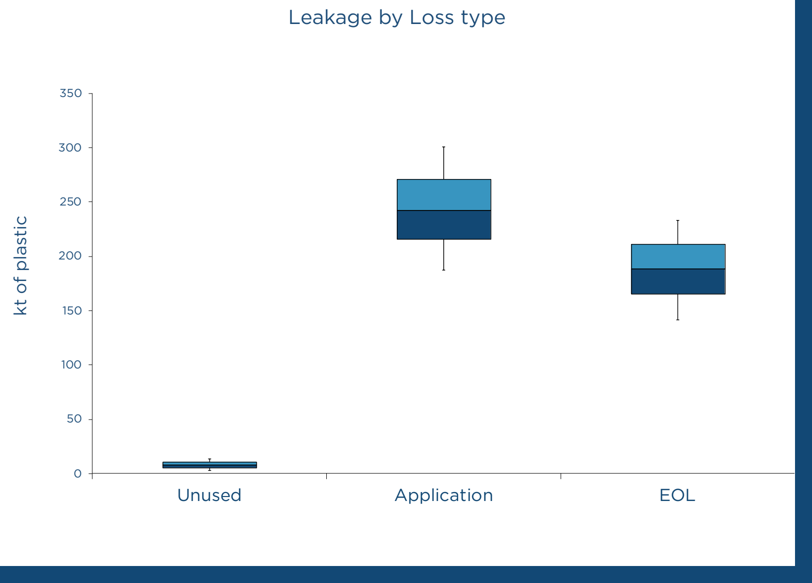
SENSITIVITY ANALYSIS

Modelling the amount of leakage coming from industrial wood paint required various modelling assumptions. A sensitivity analysis, using Monte Carlo simulations, was performed to test a range of uncertainty of most of the modelling steps and assess the impact on the results. The box plot shows the plastic leakage for the different loss types of Industrial Wood paint.

Leakage of industrial wood paint to the environment is estimated to be in the rage:

- 432 kt – 446 kt 50% confidence interval.
- 418 kt - 459 kt 95% confidence interval.





The small range of the confidence interval of industrial paint leakage is due to the fact that both application losses and EOL losses of non-recycled paint, are modelled in the same way, i.e. they both go through the solid waste pathway. This is a limitation of the model, due to the fact that we did not perform an analysis on the fate of waste management from a producer of industrial wood applications. This would be needed to have a better understanding of the probable fates of paint from overspray losses at application.

Limitations of the study

The greatest uncertainty for industrial wood is knowing how much of the painted industrial wood is recycled, and what happens to the paint during the recycling process.

SECTION

4

APPENDIX

SECTION

4.0

GENERAL APPENDIX

1. SCOPE OF THE STUDY
2. WEAR & TEAR PROCESS
3. SENSITIVITY ANALYSIS
4. PATHWAYS TO FATES

1. SCOPE OF THE STUDY

The study aims at quantifying **plastic** pollution from paint. It focuses solely on the plastic share of the paint system.

The analysis is performed at **global** level, by providing a split by region and income level.

Paint is used on many different applications. To help the modelling we grouped the applications in **six sectors**, Architectural, Marine, Road Markings, General Industrial, Automotive, Industrial Wood, plus a sector Others, which includes applications such as aerospace and packaging. All the six sectors that have been identified have been modelled independently and an estimate of their contribution to plastic leakage was provided. For the Others sectors, the amount of paint as well as the plastic content is known and it accounts for 4.5% of the total paint demand, but we did not model it or provided and estimate of the paint leakage.

The study takes a **mass conservation** approach, and tracks paint throughout its lifetime. Paint can be lost before reaching its supporting material (Application, repainting), it can detach from it (Wear & Tear, Removal), or it can be disposed with or without it (Unused, EOL). We do not account for the possible losses happening during the manufacturing of paint and plastics. Additionally, we do not model possible leakage coming from paint Embedded in new products, this includes for example paint embedded in recycled asphalt or left on granulate concrete after recycling and used for road foundation.

The reference year of the study is **2019**, in the sense that the global paint demand is that of 2019. Since we then follow paint through the entire lifetime of the object on which it is applied, the losses and leakage will take place several years in the future. If a steady state scenario is considered, then the cumulative losses of the paint put on the market in 2019, will be the same as the yearly 2019 losses of all of the paint already applied and in use.

The present report has been submitted to a consultation process. Experts in the field of microplastic research, plastic pollution specialists, environmental consultants and paint industry representatives have been reviewing the work in its version of November 2021. The comments and feedback that were not already implemented in this new version are reported in the following file, together with an appropriate comment or explanation from the EA research team.

Consultation link

2. WEAR & TEAR – REMOVAL - REPAINT CYCLE

Understanding the Wear & Tear process of paint and being able to accurately modelling it is key in estimating paint leakage to the environment. Currently, literature on this topic is lacking, therefore we propose here our own model for the wear & tear process of paint, based on a few assumptions:

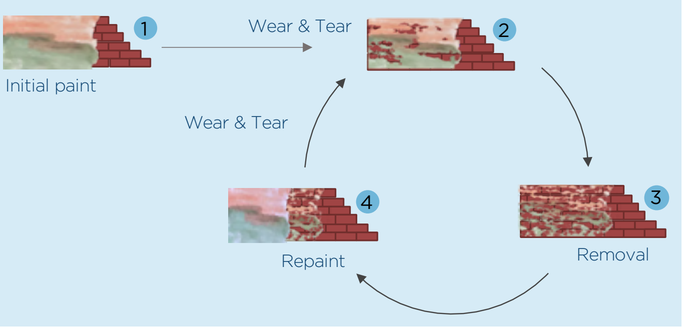
- Losses due to Wear & Tear increase with time. For simplicity we assume a linear increase.
- Wear & Tear happens in a localized fashion, meaning that if the outmost layer of paint (top-coat) is affected in a certain place, then the deeper layers will also be affected.

The latter point is important because it implies that when an object is repainted, and a new layer is added, the first layer of paint can still undergo Wear & Tear.

The main function of paint is to protect the surface underneath. When paint undergoes Wear & Tear it leaves the surface exposed, and, therefore, repaint is needed.

Most of the time, before repainting, there is a need for surface preparation, which includes paint removal.

This cycle repeats itself during the lifetime of the object.



By putting together the assumptions we made on the Wear & Tear process and the cyclical nature on the Wear & Tear-Removal-Repaint cycle, we can draw what happens to the paint applied on a surface.

The thicker line shows the effect of Wear & Tear and Removal on the first layer of paint over time, the lighter line shows the second layer of paint.

At each repaint a new layer of paint is applied. The amount of paint applied at repaint can vary and can lead to a build up of paint over time.

We introduce here L_w and L_r, which are the Wear & Tear and removal loss rate, respectively.

Figure 1. Schematic representation of Wear & Tear, removal and repaint cycle

From Figure 1, we define L_w and L_r as:

$$L_w = \frac{(A_2 - A_1)}{A_1}$$

$$L_r = \frac{(A_3 - A_2)}{A_2}$$

Where A_i is the amount of paint on the wall at time i, for i = 1,2,3. In other words, L_w is the ratio between the paint lost due to Wear & Tear during a Wear & Tear cycle and the paint applied on the wall at the beginning of the cycle. Both L_w and L_r take value in the interval (0,1), and are indicated with percentages.

The cumulative losses due to removal and Wear & Tear during the entire lifetime of the surface, can be computed by accumulating losses over several cycles.

Cumulative Wear & Tear loss rate:

$$C_{w1} = L_w\,(1 + (1\text{-}L_w)(1\text{-}L_r) + \dots + ((1\text{-}L_w)(1\text{-}L_r))^n) = L_w\,\frac{((1-Lw)(1-Lr))^{n+1} - 1}{(1-Lw)(1-Lr) - 1}$$

Cumulative removal loss rate:

$$C_{r1} = L_r(1\text{-}L_w)(1 + (1\text{-}L_w)(1\text{-}L_r) + \dots + ((1\text{-}L_w)(1\text{-}L_r))^{n-1}) = L_r(1\text{-}L_w)\,\frac{((1-Lw)(1-Lr))^n - 1}{(1-Lw)(1-Lr) - 1}$$

With n the number of repaint jobs. In Figure 1, n would be 3. The last equality holds only if n>2, otherwise the first formula needs to be used.

The number of repaint jobs n is usually determined as the ratio between the lifetime of the object, T_{life} and the interval between repaint jobs $T_{repaint}$:

$$n = \left[\frac{T_{life}}{T_{repaint}}\right]$$

The square brackets indicates that the nearest integer is chosen.

The two formulas to compute cumulative Wear & Tear, $C_{w1,}$ and removal loss rates, C_{r1}, only track the losses from the first layer of paint. The paint put on the market in 2019 might as well be used for one of the repaints job. Therefore the global loss rates due to paint weathered and removed would be:

$$C_w = p_1\,C_{w1}(L_w,L_r,n) + \sum_{j=2}^{n-1} p_{repaint}\,C_{wj}(Lw,Lr,n-j)$$

$$C_r = p_1\,C_{r1}(L_w,L_r,n) + \sum_{j=2}^{n-1} p_{repaint}\,C_{rj}(Lw,Lr,n-j)$$

where $p_{repaint}$ is the probability that the paint put on the market in 2019 will be used for a repaint job, while p_1 is the probability that it will be used for the first paint job. The two probabilities are defined as:

$$p_1 = \frac{A_1}{A_1 + (n-1)Arepaint} = \frac{1}{1 + (n-1)(Lw\,(1 - Lw)\,Lr + E)}$$

$$p_{repaint} = 1 - p_1$$

with $A_{repaint}$ amount of paint applied at repaint, $A_{repaint} = A_1(L_w\,(1 - L_w)\,L_r + E)$.

E is the excess of paint applied at repaint. $E = A_4 - A_1 / A_1$.

The total amounts of paint lost to Wear & Tear and Removed will be:

$$A_w = Q\,C_w$$

$$A_r = Q\,C_r$$

Where Q is the total amount of paint applied.

In the Appendix of each sector Loss tables can be found that contain information of Wear & Tear rates, removal practices and repaint jobs.

Losses	Loss rates	Uncertainty	Notes
Unused	U	medium	-
Application	L_a	medium	-
Wear & Tear	L_w	medium	-

Losses parameters	Value	Uncertainty	Notes
Removal factor	L_r/L_w	low	-
Re-application	E	low	-
Repaint yr	$T_{repaint}$	low	-
Lifetime yr	T_{life}	high	-

L_w, L_r, $T_{repaint}$, T_{life} and E have been defined in this section. U is the fraction of paint that is Unused. L_a is the loss rate at application (e.g. overspraying) and is defined as the ratio between the paint loss at application over the paint not Unused.

The Losses table format introduces the Uncertainty parameter, which is used for the sensitivity analysis. The Notes column instead is used in Appendix to link to explanations that justify the choice of parameters, here it is shown simply for

3. SENSITIVITY ANALYSIS

The sensitivity analysis is used to observe how an uncertainty on input parameters propagates to the output values and to provide a confidence interval for the results.

Since research on microplastic emission from paint is a novel field of research, there is not an abundance of data, rather the opposite, so that it is not possible to do a statistical analysis on an input parameter in order to determine a mean value and a standard deviation. In order words, it is not possible to compute the uncertainty on the input parameters. The approach we choose is therefore more qualitative. For each input parameter we propose one value, acting as the mean, chosen based on literature review, and a qualitative Uncertainty, «low», «medium», or «high».

Uncertainty	range
low	2%
medium	6%
high	12%
none	0%

The range corresponds to the half width of a uniform distribution, centred around the mean value, if the mean value is a percentage. Otherwise, the range needs to be multiplied by the mean value in order to determine the half width.

Once all parameters have a mean and a range assigned, a Monte Carlo analysis is performed. This consists in running the model a high number of times (1000 times in our case), by taking as input parameters a random realisation from their uniform distribution. All the 1000 outputs obtained are then analysed in order to determine a confidence interval.

4. PATHWAYS TO FATES

Pathways and Fates are two of the redistribution categories accounted for in the analysis. The Pathways represent the compartments where paint is first discarded or lost, they can vary slightly from sector to sector, but they include Soil, Ocean & Waterways, Waste water, Road runoff and Solid waste disposal. We do not account for air as a possible pathway, as we assume paint lost in air will precipitate and distribute to one of the other Pathways. The Fates on the other end, are the final compartments ultimately reached by paint and they are: Ocean & Waterways (which includes rivers, lakes, seas), Land (which includes soil, unsanitary landfills, dumpsites), Well managed (which includes incineration and sanitary landfill), and Embedded in new products.

Ultimately the distinction between Pathways and Fates is a matter of timeline. It is probably worth thinking at Pathways as the compartments reached by the lost paint within days and Fates as the compartments reached after a year.

SOIL PATHWAY

The redistribution of paint microplastics from Soil to Fates, implies an understanding of microplastic transport mechanisms from Soil to Waterways. For microplastics, the Soil can be a permanent sink, or it can be a pathway to Waterways through surface runoff and erosion. After performing a literature review and exchanging with experts from the field, we developed a model, inspired on a quantitative analysis of the erosion pathway by *Rehm et al., 2021.* The main conclusion of the paper is that microplastic is more easily mobilised than Soil, i.e.:

$$ER = \frac{\text{MP concentration in eroded soil}}{\text{MP concentration in topsoil}} > 1,$$

where ER is the Enrichment Ratio and MP stands for microplastic. The work by *Rehm et al. 2021* is based on a single experimental set-up, and the article stops short of proposing a generalised forumula for MP transport. Nevertheless, it is, to the best of our knowledge, the only article that attemps at quantifying the erosion pathway based on experimental data, and, therefore, we use their findings to build a Soil to Waterways MP transport model.

The Enrichment Ratio can be rewritten as:

$$ER = \frac{\text{MP Leaked to Ocean / Soil eroded}}{\text{MP Leaked to Soil / Topsoil}} > 1,$$

$$ER = \frac{\text{MP Leaked to Ocean/MP Leaked to Soil}}{\text{Soil eroded/Topsoil}} > 1.$$

The numerator in the formula above gives the redistribution from Soil to Waterways and it is the final percentage that we are interested in. In order to derive a value for it, we still need determine a value for ER. In *Rehm et al. 2021,* ER takes values between 1 and 10; for this study we use the middle point of the range, i.e. ER = 5.5. Finally, we need to determine the amount of Soil eroded and the amount of topsoil. To determine the Soil eroded we use regionalised Soil erosion data by *Borelli et al. 2013,* which proposes a split of continent surface areas by different erosion classes. Each erosion class is link to a range of Soil erosion computed in Mg/ha/yr, the weighted average of the Soil erosion classes by the surface areas gives the final erosion per continent.

Continent	class 1-2	class 3	class 4	class 5-7	Average erosion (t/ha)	Surface (Mha)	Soil eroded (Mt)
Africa	80%	6%	6%	8%	3.00	3037	9120
Asia	81%	5%	7%	8%	3.02	4458	13441
Europe	95%	2%	2%	2%	1.47	1018	1494
North America	88%	4%	4%	4%	2.19	2471	5409
South America	82%	5%	5%	8%	3.03	1784	5406
Oceania	96%	2%	1%	1%	1.27	853	1086

Soil erosion (Mg/ha)	1.0	3.5	7.5	20.0

Global topsoil eroded (Mt)	35955

The split by class, from 1 to 7, is taken by *Borelli et al., 2013,* the Soil erosion in Mg/ha for each class are taken within the intervals proposed by the European Soil Bureau classification, but they are chosen such that the final global Soil erosion matches the one in *Borelli et al. 2013*, of 35.9 Mt/year.

For the amount of Topsoil by continent, we assume that it is the first cm of Soil that is mobilised, and we obtain a ratio of Soil eroded / Topsoil.

Continent	Soil eroded (Mt)	Total topsoil (Mt) [1cm depth]	Soil eroded /Topsoil
Africa	9120	4.0E+05	2.26%
Asia	13441	5.9E+05	2.27%
Europe	1494	1.4E+05	1.10%
North America	5409	3.3E+05	1.65%
South America	5406	2.4E+05	2.28%
Oceania	1086	1.1E+05	0.96%

Using an ER of 5.5 and mapping the Soil erosion / Topsoil ratios from continental to regional values, we obtain that the following redistribution from Soil to Fates for microplastics.

Redistribution of microplastics from Soil Pathway to Fates for the different regions:

Region - Income	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*
Europe - High Income	6.1%	0%	93.9%	0%	*100%*
Europe - Lower Income	6.1%	0%	93.9%	0%	*100%*
MEA - High Income	12.4%	0%	87.6%	0%	*100%*
MEA - Lower Income	12.4%	0%	87.6%	0%	*100%*
Asia-Pacific - High Income	11.3%	0%	88.7%	0%	*100%*
Asia-Pacific - Lower Income	11.3%	0%	88.7%	0%	*100%*
Latin America - High Income	12.5%	0%	87.5%	0%	*100%*
Latin America - Lower Income	12.5%	0%	87.5%	0%	*100%*
North America - High Income	9.1%	0%	90.9%	0%	*100%*
North America - Lower Income	9.1%	0%	90.9%	0%	*100%*

Notice that High income and Lower income countries within a region have the same redistribution rates, this due to lack a sub-continental split of Soil erosion data. Moreover, it is important to highlight that the choice of 1cm depth for the computation of the total Topsoil volume highly impacts the final release rate from Soil to Waterways: a topsoil volume computed over 10cm depth would reduce by a factor 10 the release rate. Available literature on estimated release rates from Soil to Waterways gives a wide range of values from 0.2% (*Schell et al. 2022*) to 73% (*Nizetto et al. 2016*). In *Rehm et al. 2021* simulated 15min heavy rain events would lead to the loss of 4% of the microplastics present in the soil sample. Here the average yearly release rates proposed are in between 6 and 13%. Ultimately, we call for further research on the topic and we hope that work done here can serve as a useful framework for future studies. It is worth reminding that the redistribution of microplastics from Soil to Waterways does not affect the overall leakage to the environment, as both Soil and Waterways are environmental compartments.

For macroplastic redistribution from Soil to Waterways we use instead a 10% rate, based on based on Jambeck work on macroplastic leakage (*Jambeck et al., 2015*).

Redistribution of macroplastics from Soil Pathway to Fates for the different regions:

Region - Income	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*
Europe - High Income	10%	0%	90%	0%	*100%*
Europe - Lower Income	10%	0%	90%	0%	*100%*
MEA - High Income	10%	0%	90%	0%	*100%*
MEA - Lower Income	10%	0%	90%	0%	*100%*
Asia-Pacific - High Income	10%	0%	90%	0%	*100%*
Asia-Pacific - Lower Income	10%	0%	90%	0%	*100%*
Latin America - High Income	10%	0%	90%	0%	*100%*
Latin America - Lower Income	10%	0%	90%	0%	*100%*
North America - High Income	10%	0%	90%	0%	*100%*
North America - Lower Income	10%	0%	90%	0%	*100%*

WASTE WATER PATHWAY

The redistribution of paint microplastics from Waste water to Fates, is based on the Plastic Leak Project (PLP) methodology (*Peano et al., 2019*). In the PLP methodology, the microplastic release from Waste water to Fates happens in two steps, an «initial release» and a «final release». The release compartments are: ocean, freshwater, soil and other terrestrial compartments. The redistribution between the initial release and the final release includes: redistribution of microplastic from Soil to Waterways, and redistribution from Waterways to Ocean. Since we consider Ocean & Waterways as a single compartment we do not need to redistribute from Waterways to Ocean. For the redistribution from Soil to Waterways, the PLP methodology uses a 73% redistribution rate based on the theoretical paper on microplastics transport in the Thames watershed by *Nizzetto et al., 2016*. In light of the analysis performed in the previous section on Soil to Waterways pathway, we replace the 73% release rate with the regional release rates derived based on soil erosion.

Redistribution from Waste water to Fates for the different regions:

Region - Income	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*
Europe - High Income	19%	33%	49%	0%	*100%*
Europe - Lower Income	59%	16%	24%	0%	*100%*
MEA - High Income	57%	18%	25%	0%	*100%*
MEA - Lower Income	84%	7%	10%	0%	*100%*
Asia-Pacific - High Income	28%	30%	42%	0%	*100%*
Asia-Pacific - Lower Income	78%	9%	13%	0%	*100%*
Latin America - High Income	55%	19%	26%	0%	*100%*
Latin America - Lower Income	55%	19%	26%	0%	*100%*
North America - High Income	33%	27%	39%	0%	*100%*
North America - Lower Income	32%	28%	40%	0%	*100%*

ROAD PATHWAY

The redistribution of paint microplastics from Road runoff to Fates, is based on the Plastic Leak Project (PLP) methodology (*Peano et al., 2019*), with some modifications to take into account the new modelling of transport from Soil to Waterways (see «Soil pathway» section). We assume that in urban areas 75% of the road runoff water will be collected in combined sewer systems and join the Waste water pathway, while the remaining 25% will go to separated sewer systems and be directly discharged to Waterways. For rural areas, the hypothesis is that 25% of the water is collected in separate sewer systems (leakage to Waterways), while the remaining 75% is not collected and is dispersed to the surrounding Soil. From here some will find its way to Waterways based on the Soil to Waterways pathway (see «Soil pathway» section).

Redistribution from Road runoff to Fates for the different regions:

Region - Income	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*
Europe - High Income	36%	19%	45%	0%	*100%*
Europe - Lower Income	54%	9%	37%	0%	*100%*
MEA - High Income	62%	12%	26%	0%	*100%*
MEA - Lower Income	58%	3%	39%	0%	*100%*
Asia-Pacific - High Income	41%	19%	40%	0%	*100%*
Asia-Pacific - Lower Income	55%	4%	41%	0%	*100%*
Latin America - High Income	63%	12%	25%	0%	*100%*
Latin America - Lower Income	59%	11%	30%	0%	*100%*
North America - High Income	47%	17%	36%	0%	*100%*
North America - Lower Income	45%	17%	38%	0%	*100%*

SOLID WASTE PATHWAY

To assess the Solid waste management we use What a Waste database (*Kaza et al., 2018*), which gathers municipal solid waste management data for all countries, together with the assumption, based on Jambeck work on macroplastic leakage (*Jambeck et al., 2015*), that 10% of the waste that is uncollected or improperly disposed to dumpsite or unsanitary landfill, will leak to the Ocean. The remaining 90% of the waste that is uncollected and improperly disposed is considered leaked to Land. The waste that is not uncollected or improperly disposed is accounted for as well managed (e.g. sanitary landfill and incineration facilities).

In order to determine the portion of waste that is mismanaged or uncollected by region starting from What a waste database, we use the methodology described in *PLASTEAX, 2022*.

Redistribution of macroplastic from Solid waste to Fates for different regions:

Region - Income	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*
Europe - High Income	0.5%	95%	4.8%	0%	*100%*
Europe - Lower Income	8.2%	18%	74%	0%	*100%*
MEA - High Income	2.3%	77%	21%	0%	*100%*
MEA - Lower Income	8.6%	14%	78%	0%	*100%*
Asia-Pacific - High Income	0.1%	99%	1.1%	0%	*100%*
Asia-Pacific - Lower Income	6.7%	33%	60%	0%	*100%*
Latin America - High Income	2.8%	72%	25%	0%	*100%*
Latin America - Lower Income	4.7%	53%	42%	0%	*100%*
North America - High Income	0.0%	100%	0.1%	0%	*100%*
North America - Lower Income	2.6%	74%	23%	0%	*100%*

When microplastics is assigned to the Solid waste pathway instead (for example from paint dust collected during removal), we assume that the split between uncollected, improperly disposed and well managed will be the same as for macroplastic waste. The redistribution from uncollected to Ocean & Waterways, though, is modelled using the Soil pathway (see «Soil pathway» section). On the other hand, we assume that improper disposal of microplastic to unsanitary landfill or dumpsite will not lead to leakage to Ocean & Waterways

Redistribution of microplastic from Solid waste to Fates for different regions:.

Region - Income	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*
Europe - High Income	0.2%	95%	5.2%	0%	*100%*
Europe - Lower Income	1.6%	18%	81%	0%	*100%*
MEA - High Income	0.2%	77%	23%	0%	*100%*
MEA - Lower Income	5.9%	14%	81%	0%	*100%*
Asia-Pacific - High Income	0.1%	99%	1.1%	0%	*100%*
Asia-Pacific - Lower Income	4.5%	33%	63%	0%	*100%*
Latin America - High Income	1.0%	72%	27%	0%	*100%*
Latin America - Lower Income	2.0%	53%	45%	0%	*100%*
North America - High Income	0.0%	100%	0.1%	0%	*100%*
North America - Lower Income	0.6%	74%	25%	0%	*100%*

For the fate Special waste, in lack of better data, we assume that the leakage to Land and to Ocean & Waterways will be reduced by half with respect to the Solid waste to fate mapping (for both micro- and macro-plastics).

For other types of Pathways that can differ between Sectors, the mapping to the Fates is described in the Sector Appendix.

SECTION

4.1

APPENDIX

ARCHITECTURAL

1. Paint Demand
2. Use Cases
3. Regions
4. Losses
5. Pathways
6. Fates

ARCHITECTURAL

1. PAINT DEMAND

Sector	Plastic content 2019 kt	Uncertainty	Notes
Architectural	10801	low	[1]

[1] MarketsandMarkets Research Private Limited

2. USES

Uses	Shares	Uncertainty	Notes
Interior	71%	medium	[1]
Exterior - concrete	17%	medium	[1]
Exterior - wood	13%	medium	[1]
Tot	100%		

[1] The split of plastic demand of architectural paint between "Interior", "Exterior - concrete" and "Exterior - wood", is estimated based on the European market as reported by Eunomia (*Hann. S. et al., 2018*). The original reports distinguishes between "Interior", "Exterior - walls", "Exterior - wood, metals, etc." and "Exterior - wood varnish". In this analysis, for simplicity, we consider only two main building materials: concrete and wood. The " Exterior - walls" category is here mapped to "Exterior - concrete" , while the remaining exterior categories fall under "Exterior - wood". The shares by use case are based on the demand of paint (in kt) and on the paint polymer content, which can depend on whether the paint is professional or the do-it-yourself (DIY). Paint demand and polymer content for exterior paint is based on Eunomia. The polymer content for Interior professional paint is set to 20% of wet paint. The polymer content for Interior DIY paint is set to 5% of wet paint, value taken from a study by the Dutch National Institute for Public Health and the Environment (*A. Vershoor et al., 2016*). The analysis uses the European assessment as proxy for the entire world. Several factors such as income level, weather, paint type (water-based vs solvent based), could change the interior / exterior share of paint in other regions. See discussion in Eunomia report about the potential impact of weather on interior / exterior share.

3. REGIONS

Region - Income	Income	Shares	Uncertainty	Notes
Europe - High Income	High income	10.7%	medium	[1]
Europe - Lower Income	Lower income	6.1%	medium	[1]
MEA - High Income	High income	0.7%	medium	[1]
MEA - Lower Income	Lower income	15.1%	medium	[1]
Asia-Pacific - High Income	High income	4.6%	medium	[1]
Asia-Pacific - Lower Income	Lower income	48.8%	medium	[1]
Latin America - High Income	High income	1.1%	medium	[1]
Latin America - Lower Income	Lower income	5.4%	medium	[1]
North America - High Income	High income	6.3%	medium	[1]
North America - Lower Income	Lower income	1.5%	medium	[1]
Tot		*100%*		

[1] The distribution of architectural paint by region is based on the total number of households by region and income. The total number of household for a country is based on the total population divided by the average number of people per household. The average number of people per household is based on the Database on Household Size and Composition 2019 (*United Nations, 2019*). For countries where there is no available data, the regions' average is used. Total population by country as reported by the World Bank "What a Waste" database 2.0 (*Kaza, S. et al., 2018*). The number of household by region is most likely not the only parameter that impact the amount of paint used. The income level, the paint type, the weather and the building material could be additional factors influencing the paint consumption by region, but they have not been considered here, as there are no models available on the quantitative impact they have on the paint used.

4. LOSSES

Losses	Uses	Loss rates	Uncertainty	Notes
Unused	Interior	4.8%	medium	[1]
Unused	Exterior - concrete	7.9%	medium	[1]
Unused	Exterior - wood	7.9%	medium	[1]
Application - Spray	Interior	15%	medium	[2]
Application - Spray	Exterior - concrete	15%	medium	[2]
Application - Spray	Exterior - wood	15%	medium	[2]
Application - Brush	Interior	1.6%	low	[3]
Application - Brush	Exterior - concrete	1.6%	low	[3]
Application - Brush	Exterior - wood	1.6%	low	[3]
Wear & Tear	Interior	1.5%	medium	[5]
Wear & Tear	Exterior - concrete	7.5%	medium	[4]
Wear & Tear	Exterior - wood	7.5%	medium	[4]

[1] Based on the Eunomia and the Dutch study (see Uses table), 41% of the plastic used in exterior paint is for DIY use, while for interior paint the share is 15%. OECD, 2009, estimates that 3% of the professional paint and 25% of DIY paint are unused. The Dutch study has lowered to 15% the amount of unused DIY paint (*Verschoor et al., 2016*), which was then reconfirmed in the Eunomia study (*Hann et al., 2018*). A study by the Product Stewardship Institute (*Greiner et al., 2004*) estimates the leftover DIY paint to be 2.5% to 5% of sales in the US.
For this study we use an unused rate of 3% for professional paint and of 15% for DIY paint.

[2] According to the Eunomia study, when paint is applied by spray, there is a 35% loss rate (*Hann et al., 2018*). *OECD, 2009*, proposes a loss rates of 19%. According to the *International Labour Office, 2012*, if spray is air pressured, then the loss rate is around 30%, while if it is without air, the loss is 10%. At the time the report was written, in 2012, airless spray guns were an emerging technology. We assume by now most of the paint sprayed uses this newest technology, and therefore we set the loss rate due to overspray to 15%.

[3] *OECD, 2009* assumes that 1.5% of the paint applied by brush or roller is rinsed off, the Dutch report (*Verschoor et al., 2016*) performed a test and observed that 1.6% of the applied paint was left on roller and consequently rinsed off.

Losses parameters	Uses	Value	Uncertainty	Notes
Removal factor	Interior	0.5	medium	[6]
Removal factor	Exterior - concrete	0.5	medium	[6]
Removal factor	Exterior - wood	2	medium	[6]
Re-application	Interior	33%	low	[7]
Re-application	Exterior - concrete	33%	low	[7]
Re-application	Exterior - wood	33%	low	[7]
Repaint yr	Interior	5	low	[5]
Repaint yr	Exterior - concrete	17.5	low	[4]
Repaint yr	Exterior - wood	9	low	[4]
Lifetime yr	Interior	75	high	[8]
Lifetime yr	Exterior - concrete	75	high	[8]
Lifetime yr	Exterior - wood	75	high	[8]

[4] According to the engineering consulting firm KTA (*KTA, 2017*) the "practical life [of the paint system] is considered to be the time until 5 to 10 percent coating breakdown occurs and active rusting of the substrate is present". The average paint system practical life varies depending on the environment:

- Low (atmosphere with low levels of pollution, mostly rural areas), avg 22.4 yrs, std 7.2 yrs
- Medium (urban and industrial atmospheres), avg 15.7 yrs, std 5.4 yrs
- Very high industry (industrial areas with high humidity and aggressive atmosphere), avg 11.3 yrs, std 4.4 yrs
- Very high marine (coastal and offshore areas with high sanity), avg 11.4 yrs, std 4.4 yrs

According to a study conducted on 160 building facades in Lisbon (*Dias et al., 2014*), the average service life of the paint system was 9.5 yrs, similar to the average lifetime in very high marine environment by KTA. The agreement between the two sources is, however, only partial as according to *Dias et al., 2014*, the coating service life (or practical life) corresponded to a coating degradation severity level of 20%. Repaint frequency of exterior surface of buildings in Lagos (Nigeria) was assessed through a questionnaire and ranged between 2 years on the coast to 7 years inland (*Folorunso and Ahmad, 2014*).

For wood paint, a test conducted in the 90's on wood panels painted with different paint systems and exposed to different weather conditions, showed that after 5 years, the performance evaluation of the coating (where 1 = complete failure and 10 = perfect conditions), scored on average 7/10 across 3-layer coating systems (*Kropf et al., 1994*).

In the present analysis we take a conservative approach. For exterior paint we assume repainting only happens when the coating has reached the end of its practical life, corresponding to 5%-10% wear & tear losses in 15-20 yrs for concrete and 8-10 yrs for wood.

[5] We assume that repainting of interior surfaces happens more frequently than the paint practical life would allow for, because of aesthetic and legal reasons. In New York City, for example, the Administrative Code requires owners to repaint the interior surfaces every 3 years (chapter 2, subchapter 2, article 3). We assume wear & tear of interior paint to occur at the same rate as exterior paint in rural areas, and that therefore after 22.4 years, 5%-10% of the paint would be worn off. If we make the hypothesis that on average, around the world, interior paint will be reapplied every 5 years and that wear & tear is linear in time, this would imply a wear & tear rate of 1.5% - 2% between repaint jobs.

[6] Wear & tear losses can manifest in very localised fashion, leading to the erosion of all paint layers in some areas, while leaving other areas intact. When repainting happens, the areas that have been the most damaged are prepared by removing the remaining paint. We assume that the removal losses will be proportional to the wear & tear losses. In this case for "interior" and "exterior - concrete" we assume 0.5 removal factor, while for wood surfaces the removal factor is set to 2 to take into account the fact that wood building often undergo a heavier removal process. For comparison, Eunomia report (*Hann et al., 2018*) provides CEPE estimates for removal losses to be 5%, in light of 2.5% wear & tear losses for "Exterior wood, metals, etc." paint category, i.e. a removal factor of 2.

[7] We assume that at each repaint job the whole surface is repainted for aesthetic purposes. Because paint systems are often 3-layers system, this means that 33% of the paint will be applied at each repaint (in addition to the paint that was worn off and removed - see the General Appendix).

[8] It is assumed that buildings have lifetimes ranging from 50 to 100 years (*Aktas & Bilec, 2012*).

Uses	Income	Application - Spray	Application - Brush	*Tot*	Uncertainty	Notes
Interior	High income	0%	100%	*100%*	none	[1]
Interior	Lower income	0%	100%	*100%*	none	[1]
Exterior - concrete	High income	20%	80%	*100%*	high	[2]
Exterior - concrete	Lower income	5%	95%	*100%*	medium	[3]
Exterior - wood	High income	20%	80%	*100%*	high	[2]
Exterior - wood	Lower income	5%	95%	*100%*	medium	[3]

[1] Interior paint in buildings is usually applied by brush or roller in order to avoid staining floor or furniture with over sprayed paint.

[2] Exterior paint can be applied either by brush/roller or by spray. If the paint is applied by spray, masking is needed for all windows to avoid staining due to overspray, for this reason we assume that in multi-story buildings spraying of paint is avoided and paint is rather applied with brush/roller. If we assume that the urban vs rural population split is a proxy of multi-story buildings vs detached houses, then in high income countries around 80% of the population lives in multi-story buildings (rural/urban shares as reported by *Kaza et al., 2018*), implying that 80% of the paint in high income areas is applied by roller/brush.

[3] We assume that in lower income areas brush and roller will be preferred to a spray system because they are economically more convenient. For this reason, in lower income areas, we assume that only 5% of the paint is applied by spray.

5. PATHWAYS

Losses	Uses	Special waste	Waste water	Solid waste	Inhert landfill	Recycling	Road	Soil	Ocean	*Tot*	Uncertainty	Notes
Unused	Interior	95%		5%						*100%*	high	[1]
Unused	Exterior - concrete	95%		5%						*100%*	high	[1]
Unused	Exterior - wood	95%		5%						*100%*	high	[1]
Application - Spray	Interior		5%	95%						*100%*	medium	[2]
Application - Spray	Exterior - concrete						40%	58%	2%	*100%*	medium	[3]
Application - Spray	Exterior - wood						40%	58%	2%	*100%*	medium	[3]
Application - Brush	Interior		90%	10%						*100%*	medium	[4]
Application - Brush	Exterior - concrete		90%	10%						*100%*	medium	[4]
Application - Brush	Exterior - wood		90%	10%						*100%*	medium	[4]
Wear & Tear	Interior		5%	95%						*100%*	medium	[5]
Wear & Tear	Exterior - concrete						40%	58%	2%	*100%*	high	[3]
Wear & Tear	Exterior - wood						40%	58%	2%	*100%*	high	[3]
Removal	Interior		5%	95%						*100%*	medium	[5]
Removal	Exterior - concrete			5%			38%	55%	2%	*100%*	high	[6]
Removal	Exterior - wood			30%			28%	41%	1%	*100%*	high	[6]
EOL	Interior				45%	45%	4%	6%	0.2%	*100%*	high	[7]
EOL	Exterior - concrete				45%	45%	4%	6%	0.2%	*100%*	high	[7]
EOL	Exterior - wood			45%		45%	4%	6%	0.2%	*100%*	high	[7]

[1] Depending on the legislation some or all paints are considered as hazardous waste and have to be disposed through a special waste management system (see for example *État de Vaud, 2021* or *Florida Department of Environmental Protection, 2019*). Here we assume that most of the time paint is disposed as special waste and only 5% of the time it is disposed as general solid waste.

[2] Since according to the model interior paint is never applied by spray, these values are purely theoretical. Over spraying losses would probably be collected on masking and disposed as solid waste, while a part could be still disposed to waste water due to the washing of stained surfaces.

[3] We estimate that exterior paint lost due to overspray at application or wear & tear will deposit on soil, road or ocean and waterways. A study by the Lawrence Berkeley National Laboratory (*Akbari, Rose & Taha, 2003*) examines surface coverage in Sacramento by vegetation, roofs and paved surface. On average paved surfaces cover 2.5 times the area covered by vegetation. We use this as a proxy for the road to soil split of wear & tear losses in urban areas. In rural areas instead we assume paint leaks to soil. Using the fact that 56% of the world population lives in urban areas, paint losses are redistributed between soil and road after having attributed a small percentage to ocean and waterways.

[4] The paint leftover on brush or roller is usually rinsed and disposed of to waste water. A 10% share is attributed to the solid waste pathway to account for brushes and rollers that are thrown away at their EOL.

[5] Wear & tear and removal losses of interior paint manifests itself as dust that is either disposed of as solid waste (through vacuuming or sweeping) or as wastewater (through mopping).

[6] Removal losses of exterior paint are partly collected (if shielding is put in place) and disposed to solid waste. We assign a higher share of collection and solid waste disposal to wood paint because it can be removed with a paint scraper which does not lead to volatile dust formation but rather to flakes of paint that can be more easily being disposed. When instead the paint is removed through sanding or blasting, it leads to dust formation which is highly volatile. According to *EPA, 2016* dust produced during paint removal through abrasive blasting travels 300-500 meters in the air before depositing.
The paint that is not collected deposits on road, soil, ocean and waterways (see point [3]).

[7] Dust formation during demolition is a known phenomenon and it has been investigated mostly because fine particle suspended in the air are known to be a hazardous to human health (*Ebadian et al., 1996 - Liu et al., 2019*). Lacking quantitative estimates, we assume 10% of the paint that is still on the walls during demolition is lost to the environment as dust. Its repartition to soil, road and Ocean/waterways is the same as that at point [3]. The remaining paint follows the end of life of the supporting material. Both concrete, wood and plasterboard (the main support of interior paint) can be recycled. The EU had set a mandatory target of 70% recovery rate of construction and demolition waste by 2020, but concrete is mostly recycled as granulate that is then used backfilling or road foundations (*Wahlström et al., 2020*). On average in the EU 83% of the mineral waste from construction and demolition was "recycled" in 2016 (*European Environment Agency, 2021*). The recycling ratio of concrete in the US in 2015 was also 83% (*U.S. EPA, 2015*). We consider the EU and the US case to be on the high end of the concrete recycling share in the world. Plasterboard, which is mainly made of gypsum, can be recycled into new plasterboard through a mechanical grinding and it is then refined to have a uniform texture and be re-used to form plasterboards. According to British Gypsum, a UK manufacturer of interior lining systems, paper flakes (coated with paint) can be separated from gypsum during the recycling process and used as cattle bedding (*British Gypsum, 2021*). The hazardous risk for the health of the animals and the food chain safety linked to this practice should definitely be investigated, but this is outside the scope of this analysis. Finally, painted or varnished wood is sometimes considered recyclable in order to produce wood chippings for plywood or particle board, while in some situations, regulations require painted wood to be disposed of as waste. See for example the waste management guidelines for the city of Lausanne (*Ville de Lausanne, 2021*).
We assume that of the paint that was not lost as dust during the demolition process, 50% will follow the supporting material through the recycling process and the other 50% will be disposed as waste, either in inert landfills or as general waste.

6. FATES
Fates of recycling pathway

Uses	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*	Uncertainty	Notes
Interior	1%	20%	9%	70%	*100%*	high	[1]
Exterior - concrete	3%	5%	23%	70%	*100%*	high	[1]
Exterior - wood	3%	5%	23%	70%	*100%*	high	[1]

[1] No literature could be found on paint losses during the recycling of coated supporting material, be it concrete, wood or plasterboard, but there is visual evidence that recycling of these materials involves breaking and grinding processes, sometimes conducted in open environments (especially for concrete and wood), which lead to dust formation and dispersion in the surrounding environment. See for example: *Kieran, 2018* (concrete), *KOCT, 2016* (wood), *British Gypsum, 2021* (plasterboard).
We assume that 30% of the paint will separate from the supporting material during the recycling process, some of it will be collected and well managed while some will leak to Land or to Ocean and waterways (either due to collection or to collection and improper disposal). The remaining 70% will be embedded in new product. Although tracking the fate of paint embedded in new products is outside the scope of this study, it is worth pointing out that embedding paint in new product is not a desirable practice and most likely leads to further paint leakage down the line: think about concrete granulate being used as road foundation.

SECTION

4.2

APPENDIX

MARINE

1. Paint Demand
2. Use cases
3. Losses
4. Locations
5. Pathways
6. Regions

MARINE

1. PAINT DEMAND

Sector	Plastic content 2019 kt	Uncertainty	Notes
Marine	1374	low	[1]

[1] MarketsandMarkets Research Private Limited

2. USES

Uses	Sectors	Shares	Uncertainty	Notes
Commercial - Antifouling	Commercial	12.6%	medium	[1]
Commercial - Interior	Commercial	23.5%	medium	[1]
Commercial - Superstructure	Commercial	9.5%	medium	[1]
Commercial - Hull	Commercial	38.1%	medium	[1]
Leisure - Professional - Antifouling	Leisure - Professional	3.6%	medium	[1]
Leisure - Professional - Interior	Leisure - Professional	1.0%	medium	[1]
Leisure - Professional - Superstructure	Leisure - Professional	1.2%	medium	[1]
Leisure - Professional - Hull	Leisure - Professional	4.8%	medium	[1]
Leisure - DIY - Antifouling	Leisure - DIY	3.3%	medium	[1]
Leisure - DIY - Interior	Leisure - DIY	0.2%	medium	[1]
Leisure - DIY - Superstructure	Leisure - DIY	0.8%	medium	[1]
Leisure - DIY - Hull	Leisure - DIY	1.2%	medium	[1]

[1] The split of plastic demand of marine paint between "commercial", "leisure - professional" and "leisure - DIY", as well as the its sub-split in "antifouling", "interior", "superstructure" and "hull" is estimated based on the European market as reported by Eunomia (*Hann. S. et al., 2018*). These figures can differ at country level, in Norway for example, 25% of the paint is used in the Leisure sector (*Sundt, Schulze & Syversen, 2014*).

3. LOSSES

Losses	Uses	Sectors	Loss rates	Uncertainty	Notes
Unused	-	Commercial	3%	low	[1]
Unused	-	Leisure - Professional	3%	low	[1]
Unused	-	Leisure - DIY	15%	medium	[1]
Application	-	-	15%	low	[2]
Reapplication - Spray	-	-	15%	low	[2]
Reapplication - Brush	-	-	1.6%	low	[3]
Wear & Tear	Commercial - Antifouling	-	35%	high	[4]
Wear & Tear	Commercial - Interior	-	5%	medium	[6]
Wear & Tear	Commercial - Superstructure	-	3%	medium	[7]
Wear & Tear	Commercial - Hull	-	7.5%	medium	[8]
Wear & Tear	Leisure - Professional - Antifouling	-	35%	high	[4]
Wear & Tear	Leisure - Professional - Interior	-	6%	medium	[10]
Wear & Tear	Leisure - Professional - Superstructure	-	5%	medium	[10]
Wear & Tear	Leisure - Professional - Hull	-	7.5%	medium	[10]
Wear & Tear	Leisure - DIY - Antifouling	-	35%	high	[4]
Wear & Tear	Leisure - DIY - Interior	-	7.5%	medium	[9]
Wear & Tear	Leisure - DIY - Superstructure	-	7.5%	medium	[9]
Wear & Tear	Leisure - DIY - Hull	-	7.5%	medium	[9]

[1] See note [1] of the Losses table in the Architectural paint appendix.

[2] We assume that the first time the paint is applied it will be applied by spray in a factory or at a drydock. For losses due to overspray, see note [2] of the Losses table in the Architectural paint appendix.

[3] See note [3] of the Losses table in the Architectural paint appendix.

[4] Antifouling coating is applied on boat hulls to prevent growth of biofouling. Biofouling increases the roughness of the surface of the ship's hull, and leads to corrosion of the hull surface. It also reduces the boat's maximum speed and increases fuel consumption and CO2 emissions (*Hedgpeth, 1953 - Li & Ning, 2019 - Farkas et al., 2021*). A detailed report by the US Navy from 1953 (*Hedgpeth, 1953*) indicates that the British Admiralty expected the fuel consumption due to fouling to increase by 35% to 50% for ships out of drydock in temperate waters after 6 months (depending on speed and boat size), while the US Navy assumed fuel consumption would increase by 19% over 6 months (3% monthly increase). A common type of antifouling paint is soft antifouling, self-polishing paint. Self-polishing paint wears down over time to maintain a bio-active interface between the coating and the water and prevent biofouling formation. The best performing antifouling technology has a lifetime of 5 years (*Hellio & Yebra, 2009*), after which repainting is needed.
We could not find specific literature on wear & tear losses of antifouling paint, but according to a paper by paint manufacturer International Paint Ltd. (*Finnie, 2006*), CEPE considers all the biocide contained in the antifouling paint to be released during the antifouling coating lifetime (100% loss rate). The same paper claims that the actual emission is a factor 2.9 smaller (34% loss rate). In this report we take a conservative approach, and we assume 35% loss rates.

Losses parameters	Uses	Sectors	Value	Uncertainty	Notes
Reapplication excess	Commercial - Antifouling	-	0%	none	[11]
Reapplication excess	Commercial - Interior	-	33%	low	[11]
Reapplication excess	Commercial - Superstructure	-	0%	none	[11]
Reapplication excess	Commercial - Hull	-	33%	low	[11]
Reapplication excess	Leisure - Professional - Antifouling	-	0%	none	[11]
Reapplication excess	Leisure - Professional - Interior	-	33%	low	[11]
Reapplication excess	Leisure - Professional - Superstructure	-	33%	low	[11]
Reapplication excess	Leisure - Professional - Hull	-	33%	low	[11]
Reapplication excess	Leisure - DIY - Antifouling	-	0%	none	[11]
Reapplication excess	Leisure - DIY - Interior	-	33%	low	[11]
Reapplication excess	Leisure - DIY - Superstructure	-	33%	low	[11]
Reapplication excess	Leisure - DIY - Hull	-	33%	low	[11]
Removal factor	Commercial - Antifouling	-	2	high	[12]
Removal factor	Commercial - Interior	-	1.5	high	[12]
Removal factor	Commercial - Superstructure	-	1.5	high	[12]
Removal factor	Commercial - Hull	-	1.5	high	[12]
Removal factor	Leisure - Professional - Antifouling	-	2	high	[12]
Removal factor	Leisure - Professional - Interior	-	1.5	high	[12]
Removal factor	Leisure - Professional - Superstructure	-	1.5	high	[12]
Removal factor	Leisure - Professional - Hull	-	1.5	high	[12]
Removal factor	Leisure - DIY - Antifouling	-	2	high	[12]

Removal factor	Leisure - DIY - Interior	-	1.5	high	[12]
Removal factor	Leisure - DIY - Superstructure	-	1.5	high	[12]
Removal factor	Leisure - DIY - Hull	-	1.5	high	[12]
Repaint yr	Commercial - Antifouling	-	4	medium	[5]
Repaint yr	Commercial - Interior	-	4.5	medium	[7]
Repaint yr	Commercial - Superstructure	-	0.9	medium	[6]
Repaint yr	Commercial - Hull	-	4	medium	[8]
Repaint yr	Leisure - Professional - Antifouling	-	3.5	medium	[5]
Repaint yr	Leisure - Professional - Interior	-	9.8	medium	[10]
Repaint yr	Leisure - Professional - Superstructure	-	5	medium	[10]
Repaint yr	Leisure - Professional - Hull	-	7	medium	[10]
Repaint yr	Leisure - DIY - Antifouling	-	2	medium	[5]
Repaint yr	Leisure - DIY - Interior	-	15	medium	[9]
Repaint yr	Leisure - DIY - Superstructure	-	10	medium	[9]
Repaint yr	Leisure - DIY - Hull	-	10	medium	[9]
Lifetime yr	-	Commercial	28	low	[13]
Lifetime yr	-	Leisure - Professional	30	medium	[13]
Lifetime yr	-	Leisure - DIY	30	high	[13]

[5] *Thompson Clarke Shipping Pty. Ltd, 2004*, reports that typical repaint intervals for Shipping vessel are 5 years (but it can also happen at shorter intervals of 2 to 3 years), while recreational craft generally perform a repaint every 1-2 years. The International Convention for Safety of Life at Sea (SOLAS) requires commercial ships to dock twice every 5 years for hull inspection, meaning that interval between drydockings cannot exceed 5 years. An interview with a local harbour on Geneva lake offered an estimate of 2-3 years repaint interval for Leisure - DIY. For the current analysis we choose the following repaint intervals for antifouling paint: 3-5 years for Commercial, 1-3 years for Leisure - DIY and an in-between (3-4 years) for Leisure - Professional.

[6] The "Coating and color manual" of the US Coast Guard instructs not to repaint interior spaces more than once every 3 years to avoid film failure (*US Coast Guard, 2014*). We here assume this to be a lower boundary for repaint works on Commercial vessels and for the average repaint time to be between 3-6 years. The corresponding 5% wear & tear rate is taken from the low end of the wear & tear losses to be expected when the paint reaches the end of its service life (*KTA, 2021*).

[7] Repaint work on the boat superstructure of Commercial boats happens on board and therefore can be performed as needed to treat localised paint system failure and avoid corrosion of the metal substrate. We assume average losses between repaint interval to be small (3%) and to be treated within 4 to 18 months.

[8] The underwater part of the hull of a commercial boat will be repainted during drydocking (every 3-5 years, see note [5]). The hull paint above water could be painted more frequently (*US Coast Guard, 2014)*, while the boat is at sea. For sake of simplicity, we consider the underwater and above water hull paint maintenance as a whole and we assume that it takes place during drydocking. As for the wear & tear losses we assume that the paint system has reached the end of its service life when the boat is taken to maintenance at drydock, and therefore we assign a 5%-10% loss rate.

[9] We assume that repainting of Leisure - DIY boats is done when the paint system reaches the end of its service lifetime, i.e., 5% - 10% loss rate (*KTA, 2021*). At the same time, in choosing how long it will take before the paint system fails, we take into consideration the fact that leisure boat can more often be stored out of the water, which would reduce the speed at which wear & tear takes place. According to *KTA, 2021*, the average paint system service life in "seacoast" weather is 11.4 years. Overall, we assume that leisure DIY hull and superstructure is repainted on average every 10 years, while the interior will need repainting every 15 years.

[10] For wear & tear loss rates of paint of the Leisure - Professional sector and their repaint times, we choose the average between the values for Commercial and for Leisure - DIY.

[11] In terms of repainting, we consider that antifouling paint will be largely worn off or removed before reapplication happens, and therefore a new layer of antifouling paint will be applied, without excess of paint. For Commercial superstructure, we assume that paint removal and reapplication will be limited to the affected area (no reapplication excess). For the other paint types, we assume that the area affected by wear & tear and removal will be treated but, additionally the top coating will be applied everywhere for aesthetic purposes.

[12] Antifouling paint usually undergoes more extensive removal than other types of paint, but the practice might vary a lot, especially for Leisure - DIY.

[13] Lifetime of commercial boats is 25 to 30 years (*National Geographic, 2014*). Lifetime Leisure boats can vary greatly, some sources indicate 10-15 while other 25-30. *Eklund, 2013* reports that 20% of EU boats are more than 40 years old.

Uses	Reapplication - Spray	Reapplication - Brush	*Tot*	Uncertainty	Notes
Commercial - Antifouling	95%	5%	*100%*	medium	[1]
Commercial - Interior	5%	95%	*100%*	medium	[1]
Commercial - Superstructure	5%	95%	*100%*	medium	[1]
Commercial - Hull	95%	5%	*100%*	medium	[1]
Leisure - Professional - Antifouling	50%	50%	*100%*	high	[1]
Leisure - Professional - Interior	5%	95%	*100%*	high	[1]
Leisure - Professional - Superstructure	5%	95%	*100%*	high	[1]
Leisure - Professional - Hull	50%	50%	*100%*	high	[1]
Leisure - DIY - Antifouling	5%	95%	*100%*	medium	[1]
Leisure - DIY - Interior	5%	95%	*100%*	medium	[1]
Leisure - DIY - Superstructure	5%	95%	*100%*	medium	[1]
Leisure - DIY - Hull	5%	95%	*100%*	medium	[1]

[1] Interior paint is applied by brush/roller to avoid staining furniture or machinery, independently of the sector. We assume that Commercial Antifouling and Hull paint is mostly applied by spraying, while Commercial superstructure paint is applied by brush or roller since repaint jobs concern localised areas, additionally since the repaint jobs happen aboard, the wind at sea would lower the transfer efficiency of spraying guns. Because of the small size, we assume that Leisure - DIY boats are painted by roller or brush. For Leisure professional we use average value between Leisure - DIY and Commercial.

4. LOCATIONS

Losses	Uses	Harbor	Backyard	Dock	Onboard - Interior	Onboard - Exterior	Beach	Factory	Ship graveyard	Boat disposal	Abandoned	Special waste	*Tot*	Uncertainty	Notes
Unused	-											100%	*100%*	none	[1]
Application	Commercial - Antifouling			100%									*100%*	none	[2]
Application	Commercial - Interior							100%					*100%*	none	[2]
Application	Commercial - Superstructure			67%				33%					*100%*	low	[2]
Application	Commercial - Hull			67%				33%					*100%*	low	[2]
Application	Leisure - Professional - Antifouling							100%					*100%*	none	[2]
Application	Leisure - Professional - Interior							100%					*100%*	none	[2]
Application	Leisure - Professional - Superstruct							100%					*100%*	none	[2]
Application	Leisure - Professional - Hull							100%					*100%*	none	[2]
Application	Leisure - DIY - Antifouling							100%					*100%*	none	[2]
Application	Leisure - DIY - Interior							100%					*100%*	none	[2]
Application	Leisure - DIY - Superstruct							100%					*100%*	none	[2]
Application	Leisure - DIY - Hull							100%					*100%*	none	[2]
Reapplication - Spray or Brush	Commercial - Antifouling			100%									*100%*	none	[3]
Reapplication - Spray or Brush	Commercial - Interior			5%	95%								*100%*	low	[3]
Reapplication - Spray or Brush	Commercial - Superstructure			5%		95%							*100%*	low	[3]
Reapplication - Spray or Brush	Commercial - Hull			100%									*100%*	none	[3]
Reapplication - Spray or Brush	Leisure - Professional - Antifouling	50%		50%									*100%*	high	[4]
Reapplication - Spray or Brush	Leisure - Professional - Interior	50%			50%								*100%*	high	[4]
Reapplication - Spray or Brush	Leisure - Professional - Superstruct	50%				50%							*100%*	high	[4]
Reapplication - Spray or Brush	Leisure - Professional - Hull	50%		50%									*100%*	high	[4]
Reapplication - Spray or Brush	Leisure - DIY - Antifouling	70%	10%				20%						*100%*	medium	[5]
Reapplication - Spray or Brush	Leisure - DIY - Interior	70%	10%				20%						*100%*	medium	[5]
Reapplication - Spray or Brush	Leisure - DIY - Superstruct	70%	10%				20%						*100%*	medium	[5]
Reapplication - Spray or Brush	Leisure - DIY - Hull	70%	10%				20%						*100%*	medium	[5]

Losses	Uses	Harbor	Backyard	Dock	Onboard - Interior	Onboard - Exterior	Beach	Factory	Ship graveyard	Boat disposal	Abandoned	Special waste	*Tot*	Uncertainty	Notes
Wear & Tear	Commercial - Antifouling					100%							*100%*	none	[6]
Wear & Tear	Commercial - Interior				100%								*100%*	none	[6]
Wear & Tear	Commercial - Superstructure					100%							*100%*	none	[6]
Wear & Tear	Commercial - Hull					100%							*100%*	none	[6]
Wear & Tear	Leisure - Professional - Antifouling					100%							*100%*	none	[6]
Wear & Tear	Leisure - Professional - Interior				100%								*100%*	none	[6]
Wear & Tear	Leisure - Professional - Superstructure					100%							*100%*	none	[6]
Wear & Tear	Leisure - Professional - Hull					100%							*100%*	none	[6]
Wear & Tear	Leisure - DIY - Antifouling					100%							*100%*	none	[6]
Wear & Tear	Leisure - DIY - Interior				100%								*100%*	none	[6]
Wear & Tear	Leisure - DIY - Superstructure					100%							*100%*	none	[6]
Wear & Tear	Leisure - DIY - Hull					100%							*100%*	none	[6]
Removal	Commercial - Antifouling			100%									*100%*	none	[3]
Removal	Commercial - Interior			5%	95%								*100%*	low	[3]
Removal	Commercial - Superstructure			5%		95%							*100%*	low	[3]
Removal	Commercial - Hull			100%									*100%*	none	[3]
Removal	Leisure - Professional - Antifouling	50%		50%									*100%*	high	[4]
Removal	Leisure - Professional - Interior	50%			50%								*100%*	high	[4]
Removal	Leisure - Professional - Superstructure	50%				50%							*100%*	high	[4]
Removal	Leisure - Professional - Hull	50%		50%									*100%*	high	[4]
Removal	Leisure - DIY - Antifouling	70%	10%				20%						*100%*	medium	[5]
Removal	Leisure - DIY - Interior	70%	10%				20%						*100%*	medium	[5]
Removal	Leisure - DIY - Superstructure	70%	10%				20%						*100%*	medium	[5]
Removal	Leisure - DIY - Hull	70%	10%				20%						*100%*	medium	[5]

Losses	Uses	Harbor	Backyard	Dock	Onboard - Interior	Onboard - Exterior	Beach	Factory	Ship graveyard	Boat disposal	Abandoned	Special waste	*Tot*	Uncertainty	Notes
EOL	Commercial - Antifouling								100%				*100%*	none	[7]
EOL	Commercial - Interior								100%				*100%*	none	[7]
EOL	Commercial - Superstructure								100%				*100%*	none	[7]
EOL	Commercial - Hull								100%				*100%*	none	[7]
EOL	Leisure - Professional - Antifouling								50%	50%			*100%*	high	[8]
EOL	Leisure - Professional - Interior								50%	50%			*100%*	high	[8]
EOL	Leisure - Professional - Superstructure								50%	50%			*100%*	high	[8]
EOL	Leisure - Professional - Hull								50%	50%			*100%*	high	[8]
EOL	Leisure - DIY - Antifouling									90%	10%		*100%*	medium	[9]
EOL	Leisure - DIY - Interior									90%	10%		*100%*	medium	[9]
EOL	Leisure - DIY - Superstructure									90%	10%		*100%*	medium	[9]
EOL	Leisure - DIY - Hull									90%	10%		*100%*	medium	[9]

[1] Unused paint should be treated as special waste (see note [1] of Pathways table in Architectural paint appendix). There is no actual "Location" associated with it, but in order to keep the same modelling structure for all losses type we add "Special waste" to the locations. In the pathways analysis, a part of the special waste will go to solid waste (see Pathways table).

[2] These values concern the application of paint during the boat manufacturing process, not the repaint jobs. For commercial ships it appears that the first layer of paint (the primer) is applied on each steel plate individually before assembly in a controlled environment ("Factory"), while the rest of the paint is applied once the boat is assembled at a building dock ("Drydock"), see for example *Marineinsight, 2020*. These assumptions are valid for hull paint and superstructure paint. Antifouling paint is applied on top of the hull paint (below water line). While interior paint is most likely physically applied once the boat is already assembled, the losses from application will most likely be disposed as solid waste, which is the eventual pathway of "Factory" location category. Given the smaller size of leisure boats, we assume that their paint application happens in "Factory" environments.

[3] Removal and repaint processes for Commercial boats happen either onboard (for Interior paint and Superstructure), or at drydock during drydocking (for Hull and Antifouling). We assume that some repaint jobs for interior and superstructure can still happen during drydocking.

[4] If Leisure - Professional paint is applied on small boats, then repaint jobs happen at harbor, if it is applied on bigger boats that need drydocking then some of the paint will be removed / reapplied at drydock and the rest will removed / reapplied onboard.

[5] We assume that most painting jobs on leisure boat with Leisure - DIY paint will be performed on small boats, mostly at harbor, but sometimes also directly on the coast ("beach") or in the owner backyard.

[6] For wear & tear losses we propose two location categories: Onboard - Interior (for interior paints) and Onboard - Exterior (for all other paints).

[7] 95% of commercial ships are dismantled in Ship graveyards in India, Bangladesh, Pakistan, China (*UNCTAD, 2017*). For more information on shipbreaking see for example: *Public Eye, 2019* or *NGO shipbreaking platform, 2021*.

[8] Leisure - Professional *paint applied on big boats (for example cruises ships) will be dismantled in ship graveyards* (Reuters, 2020), while smaller boats will mostly be managed by a dedicated waste management system ("boat disposal").

[9] Leisure - Professional paint is mostly applied on small leisure boats. At their end of life, we assume most will be disposed in dedicated waste management facilities, while some will be abandoned.

5. PATHWAYS

Locations	Ocean	Solid waste boat	Solid waste	Soil	Road	Waste water	Recycling	Special waste	Tot	Uncertainty	Notes
Harbor	15%		25%	25%	25%	10%			*100%*	medium	-
Backyard				50%	50%				*100%*	medium	-
Dock	50%		50%						*100%*	high	-
Onboard - Interior	5%	95%							*100%*	low	-
Onboard - Exterior	100%								*100%*	none	-
Beach	100%								*100%*	none	-
Factory			100%						*100%*	none	-
Ship graveyard	70%						30%		*100%*	medium	-
Boat disposal			90%				10%		*100%*	medium	-
Abandoned	50%			50%					*100%*	medium	-
Special waste			5%					95%	*100%*	medium	-

Location to pathways mapping for brush applications

Locations	Ocean	Solid waste boat	Solid waste	Soil	Road	Waste water	Recycling	Special waste	Tot	Uncertainty	Notes
Harbor	50%					50%			*100%*	high	-
Backyard						100%			*100%*	none	-
Dock	50%					50%			*100%*	high	-
Onboard - Interior	95%	5%							*100%*	low	-
Onboard - Exterior	95%	5%							*100%*	low	-
Beach	80%					20%			*100%*	medium	-
Factory	-	-	-	-	-	-	-	-	-	none	-
Ship graveyard	-	-	-	-	-	-	-	-	-	none	-
Boat disposal	-	-	-	-	-	-	-	-	-	none	-
Abandoned	-	-	-	-	-	-	-	-	-	none	-
Special waste	-	-	-	-	-	-	-	-	-	none	-

6. REGIONS

Commercial

Locations	Europe - High Income	Europe - Lower Income	MEA - High Income	MEA - Lower Income	Asia-Pacific - High Income	Asia-Pacific - Lower Income	Latin America - High Income	Latin America - Lower Income	North America - High Income	North America - Lower Income	*Tot*	Uncertainty	Notes
Harbor	-	-	-	-	-	-	-	-	-	-	-	low	[1]
Backyard	-	-	-	-	-	-	-	-	-	-	-	low	[1]
Dock					62%	38%					*100%*	low	[2]
Onboard - Interior	56%		3%	1%	27%	11%			2%		*100%*	low	[3]
Onboard - Exterior	56%		3%	1%	27%	11%			2%		*100%*	low	[3]
Beach	-	-	-	-	-	-	-	-	-	-	-	low	[1]
Factory					62%	38%					*100%*	low	[2]
Ship graveyard				4%		96%					*100%*	low	[4]
Boat disposal	-	-	-	-	-	-	-	-	-	-	-	low	[1]
Abandoned	-	-	-	-	-	-	-	-	-	-	-	low	[1]
Special waste					62%	38%					*100%*	low	[2]

[1] These locations are not related to commercial vessels.

[2] According to *UNCTAD, 2017*, 94% of building and maintenance of shipping vessels happens in Japan, China, South Korea and the Philippines. The remaining 6% is unknown and disregarded in this analysis.

[3] Losses happening onboard of the ship, when the ship is at sea, are assigned to the country of ownership of the ship. The share of ship ownership by region are based *UNCTAD, 2017*. For 7% of the vessels the ownership is not available in the report, and it is therefore disregarded in this analysis.

[4] 94.9% of commercial ships are dismantled in Ship graveyards in India, Bangladesh, Pakistan, China, 3.5% are dismantled in Turkey, and for 1.6% the fate is unspecified (*UNCTAD, 2017*). The values reported in the table are adjusted from UNCTAD after removing the unspecified portion.

Leisure

Locations	Europe - High Income	Europe - Lower Income	MEA - High Income	MEA - Lower Income	Asia-Pacific - High Income	Asia-Pacific - Lower Income	Latin America - High Income	Latin America - Lower Income	North America - High Income	North America - Lower Income	Tot	Uncertainty	Notes
Harbor	18.2%			0.3%	6.1%	0.4%	0.6%	0.2%	74.1%		100%	low	[1]
Backyard	18.2%			0.3%	6.1%	0.4%	0.6%	0.2%	74.1%		100%	low	[1]
Dock	2.1%			0.1%	0.7%	95.7%	0.1%	0.1%	1.3%		100%	low	[2]
Onboard - Interior	18.2%			0.3%	6.1%	0.4%	0.6%	0.2%	74.1%		100%	low	[1]
Onboard - Exterior	18.2%			0.3%	6.1%	0.4%	0.6%	0.2%	74.1%		100%	low	[1]
Beach	18.2%			0.3%	6.1%	0.4%	0.6%	0.2%	74.1%		100%	low	[1]
Factory	2.1%			0.1%	0.7%	95.7%	0.1%	0.1%	1.3%		100%	low	[2]
Ship graveyard				3.5%		96.5%					100%	low	[3]
Boat disposal	18.2%			0.3%	6.1%	0.4%	0.6%	0.2%	74.1%		100%	low	[1]
Abandoned	18.2%			0.3%	6.1%	0.4%	0.6%	0.2%	74.1%		100%	low	[1]
Special waste	2.1%			0.1%	0.7%	95.7%	0.1%	0.1%	1.3%		100%	low	[2]

[1] The losses associated with Locations that are linked to the use phase of the boat, or to its disposal (except for ship graveyard), are distributed by region based on share of recreational global boat park per country, by unit as provided by *ICOMIA, 2018*.

[2] The losses associated with Locations that are linked to the production phase are distributed by regions based on the share of global recreational boats production, as provided by *ICOMIA, 2018.*

[3] See note [2] of regional table for commercial vessels in Marine appendix.

SECTION

4.3

APPENDIX

ROAD MARKINGS

1. Paint Demand
2. Use Cases
3. Losses
4. Pathways
5. Regions

ROAD MARKINGS

1. PAINT DEMAND

Sector	Plastic content 2019 kt	Uncertainty	Notes
Road markings	234	low	[1]

[1] MarketsandMarkets Research Private Limited

2. USE CASES

Uses	Shares	Uncertainty	Notes
Solvent based	22%	medium	[1]
Water based	3%	medium	[1]
Thermoplastics	54%	medium	[1]
Cold plastics agglomerate	18%	medium	[1]
Cold spray plastics	4%	medium	[1]
Tot	*100%*		

[1] Eunomia, 2018 lists four different types of paint (solvent based, water based, thermoplastics, cold plastics) and provides their demand in the European market. Although it is known that different countries chose different paint types for road markings, based on climatic conditions and price (*De Witt, Smith & Visser, 2000 – Kaps et al., 2018*), in this analysis, due to lack of better data, we assume that at region-level the composition of the paint demand is the same, and mirrors the European one. The different paint types have different compositions and plastic content. The shares reported here are used to distribute the plastic used in Road Markings paint between the different types of paint.

Cold plastic road markings are often applied in the form of a cold plastic agglomerate structure, with a layer cold spray plastic applied on top. According to *JRC, 2018* the two components wear off at a different pace. For this reason we split the cold plastic paint type into the two components, by assigning 15% of the demand to Cold spray plastics and 85% to Cold plastics agglomerate. This estimate is based on the thickness of the two layers, reported by *Cruz, Klein, & Steiner, 2016.*

3. REGIONS

Region - Income	Shares	Uncertainty	Notes
Europe - High Income	16%	medium	[1]
Europe - Lower Income	6%	medium	[1]
MEA - High Income	1%	medium	[1]
MEA - Lower Income	9%	medium	[1]
Asia-Pacific - High Income	6%	medium	[1]
Asia-Pacific - Lower Income	32%	medium	[1]
Latin America - High Income	1%	medium	[1]
Latin America - Lower Income	7%	medium	[1]
North America - High Income	20%	medium	[1]
North America - Lower Income	1%	medium	[1]
Tot	*100%*		

[1] We assume the distribution of the paint by region is proportional to the kilometers of road by region, as reported by *CIA, 2021.*

4. ROAD TYPE

Region - Income	Principal	Non-Principal	*Tot*	Uncertainty	Notes
Europe - High Income	76%	24%	*100%*	high	[1]
Europe - Lower Income	65%	35%	*100%*	high	[1]
MEA - High Income	87%	13%	*100%*	high	[1]
MEA - Lower Income	47%	53%	*100%*	high	[1]
Asia-Pacific - High Income	80%	20%	*100%*	high	[1]
Asia-Pacific - Lower Income	46%	54%	*100%*	high	[1]
Latin America - High Income	89%	11%	*100%*	high	[1]
Latin America - Lower Income	79%	21%	*100%*	high	[1]
North America - High Income	82%	18%	*100%*	high	[1]
North America - Lower Income	80%	20%	*100%*	high	[1]

[1] Maintenance practices can depend on whether the road markings are applied to a Principal or Non-Principal road. We use the split between urban and rural population by region (*The World Bank, 2018*) as a proxy of Principal and Non-Principal roads.

5. LOSSES

Losses	Road type	Loss rates	Uncertainty	Notes
Unused	-	3%	low	[1]
Application	-	5%	low	[2]
Wear & Tear	Principal	30%	high	[3]
Wear & Tear	Non-Principal	70%	high	[3]
Redesign	-	90%	low	[4]

[1] See note [1] of the Losses table in the Architectural paint appendix.

[2] We assume that during application some of the paint will be leftover in the machine used to apply it. We estimate this loss rate to be 5%

[3] Eunomia, 2018, estimates that a 30% wear & tear loss is attained on Principal roads before repainting, while for Non-Principal roads and highways 70% of the road markings paint is lost before repainting is performed. A study on the assessment of pavement markings through image processing performed of the US 78 highway shows the average percentage of remaining pavement markings at 70%, or a loss rate of 30% (*Zhang & Ge, 2012*).

[4] When road markings need to be removed, because of redesigning of traffic lanes for example, it is almost unavoidable to remove some asphalt with it. For this reason, a compromise is found between total removal of the road marking with severe damage of the road and partial removal with negligible damage. A report by the National Cooperative Research Program in the US (*Pike & Miles, 2013*) indicates that the majority of the states require a 90% or 95% removal rates.

Losses parameters	Uses	Road type	Value	Uncertainty	Notes
Repaint eccess	-	-	0	low	[1]
Repaint yr	Solvent based	-	1.5	high	[2]
Repaint yr	Water based	-	1.5	high	[2]
Repaint yr	Thermoplastics	-	4	high	[2]
Repaint yr	Cold plastics agglomerate	-	4	high	[2]
Repaint yr	Cold spray plastics	-	2.5	high	[2]
Redesign yr	-	-	15	high	-
Resurface yr	-	Principal	24	high	[3]
Resurface yr	-	Non-Principal	33	high	[3]

[1] For simplicity, we assume that when paint is re-applied the new marking will have the same amount of paint as the initial marking, i.e. the Repaint excess = 0.

[2] We assume that on Principal roads the repaint interval for the different paint types will correspond to the functional life of the paint system, as reported by Kaps et al., 2018. On Non-Principal roads the repainting happens less frequently. Specifically, if we assume that wear & tear increases linearly over time, the repaint interval for Non-Principal roads will be equal to the repaint interval of Principal roads multiplied by the ratio of the wear & tear loss rate of Non-Principal over Principal roads.

[3] Regarding the resurfacing interval, we use results from a report based on UK assessment of road resurfacing (*Asphalt Industry Alliance, 2021*), which distinguishes between Principal and Non-Principal roads.

6. PATHWAYS

Losses	Special waste	Waste water	Solid waste	Road	Recycling	*Tot*	Uncertainty	Notes
Unused	95%	0%	5%	0%	0%	*100%*	low	[1]
Application	0%	90%	10%	0%	0%	*100%*	low	[2]
Wear & Tear	0%	0%	0%	100%	0%	*100%*	none	[3]
Redesign	0%	0%	90%	10%	0%	*100%*	high	[4]
Resurfacing	0%	0%	10%	0%	90%	*100%*	medium	[5]

[1] We assume that the vast majority of Unused paint, or can residue, will be disposed as Special waste, but some will be incorrectly disposed as solid waste.

[2] For the paint loss during application, the paint left over in the machine used for the application, will go to Waste Water when the machine is washed. There is a fraction that goes to solid waste, which aims at representing the practice of using tape to delimit road marks while painting in order to leave a neat line. Some paint will be applied to the tape and then thrown away with it during removal.

[3] All of the paint that wears off goes to the road runoff pathway.

[4] Removal of paint for redesign can be performed in several ways: blasting, grinding, using lasers, chemical methods and even burning (*Pike & Miles, 2013*). The literature mentions dust formation (in the case of grinding) as a health concern to the workers performing the removal, but no literature has been found on concern of pollution due to the removed paint being uncollected. Interviews conducted with road marking companies in Switzerland affirmed that the removed paint is collected, independently from the technique used. We assume that 90% of the paint is collected and disposed as solid waste, and 10% is left on the road in the form of finer dust particles and uncollected.

[5] We assume that when a road is resurfaced, the paint is not removed from the removed asphalt or concrete beforehand, and, after recycling, it will again be subject to wear & tear and finish as road runoff. 94% of the asphalt is recycled in the US (*U.S. EPA, 2015*), and 94% of the surface roads in the US are made of asphalt (*Buncher, 2019*). The remaining is made of concrete, which has an 83% recycling rate (*U.S. EPA, 2015*). Therefore, we assume that 90% of the road markings removed will follow the support material through the recycling process, while 10% will not be recycled and will end up being disposed as waste together with the supporting material. Depending on the country, a more or less important fraction of this waste will not be well managed, and it will end up in ocean and waterways or land.

7. FATES
Fates for recycling pathway

Material	Shares	Uncertainty	Notes
Concrete	6%	high	[1]
Asphalt	94%	high	[1]
Tot	*100%*		

[1] 94% of the surface roads in the US are made of asphalt (*Buncher, 2019*). We use the US values as proxy for the world split of Concrete and Asphalt.

Material	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	*Tot*	Uncertainty	Notes
Concrete	3%	5%	23%	70%	*100%*	high	[1]
Asphalt	0%	0%	0%	100%	*100%*	none	[2]

[1] See note [1] of Fates table in Architectural paint Appendix, for what concerns recycling of concrete.

[2] We assume that none of the paint left on the Asphalt will be lost to the environment during the recycling process. Nonetheless, the temperatures at which Asphalt is melted for recycling, i.e. 100 - 140 °C (*Ma et al., 2020*), are too low to change the chemical structure of plastic polymers used in Road Markings paint (depolymerisation/thermal degradation), and the plastic will become embedded in the recycled asphalt.

SECTION

4.4

APPENDIX

GENERAL INDUSTRIAL

1. Paint Demand
2. Use Cases
3. Losses
4. Pathways
5. Regions

GENERAL INDUSTRIAL

1. PAINT DEMAND

Sector	Plastic content 2019 kt	Uncertainty	Notes
General Industrial	2915	low	[1]

[1] MarketsandMarkets Research Private Limited

2. USE CASES

Uses	Shares	Uncertainty	Notes
Oil & Gas	32%	low	[1]
Petrochemical	18%	low	[1]
Cargo Containers	2%	low	[1]
Power Generation	15%	low	[1]
Water and Waste Treatment	7%	low	[1]
Others	26%	low	[1]
Tot	*100%*		

[1] MarketsandMarkets Research Private Limited

3. LOSSES

Losses	Loss rates	Uncertainty	Notes
Unused	3%	low	[1]
Application	15%	medium	[2]
Wear & Tear	7.5%	medium	[3]

Time variables	min	max	Notes
Lifetime yr	10	50	-
Repaint yr	5	15	[4]

[1] See note [1] in Losses table of Architectural paint Appendix

[2] We assume general industrial pain is applied by spraying (see note [2] in Losses table of Architectural paint Appendix).

[3] We assume applications of general industrial paint are repainted when the paint reaches the end of its lifetime. According to *KTA, 2021*, that happens when 5%-10% of the paint system is damaged.

[4] Coating of general industrial paint is mostly Epoxy or Epoxy Zinc based. According to *KTA, 2021* the minimum lifetime of these type of paint in industrial environment is 5 years, while the maximum lifetime is 15 years.

4. PATHWAYS

Losses	Ocean	Soil	Road	Solid waste	Waste water	Special waste	Recycling	Uncertainty	Notes
Unused				5%		95%		medium	[1]
Application		25%	25%	25%	25%			high	-
Wear & Tear	33%	33%	33%					high	-
Removal	25%	25%	25%	25%				high	-
EOL	15%	15%					70%	high	-

[1] See note [1] on Pathways table of Architectural paint

5. REGIONS

Region - Income	Shares	Uncertainty	Notes
Europe - High Income	10%	medium	[1]
Europe - Lower Income	4%	medium	[1]
MEA - High Income	2%	medium	[1]
MEA - Lower Income	5%	medium	[1]
Asia-Pacific - High Income	7%	medium	[1]
Asia-Pacific - Lower Income	61%	medium	[1]
Latin America - High Income	0%	medium	[1]
Latin America - Lower Income	2%	medium	[1]
North America - High Income	7%	medium	[1]
North America - Lower Income	2%	medium	[1]

[1] We make the hypothesis that steel is the main surface on which general industrial paint is applied. The share of paint by region is here based on the steel use by country in 2018, as provided by *World Steel Association, 2021*.

SECTION

4.5

APPENDIX

AUTOMOTIVE

1. Paint Demand
2. Use Cases
3. Losses
4. Pathways
5. Regions

AUTOMOTIVE

1. PAINT DEMAND

Sector	Plastic content 2019 kt	Uncertainty	Notes
Automotive	2041	low	[1]

[1] MarketsandMarkets Research Private Limited

2. USE CASES

Uses	Shares	Uncertainty	Notes
Automotive OEM	71%	low	[1]
Automotive Refinish	29%	low	[1]
Tot	*100%*		

[1] "Automotive OEM" stands for Original Equipment Manufacturer and refers to the paint applied during the manufacturing process, while "Automotive Refinish" refers to the paint applied at a later stage for example due to an accident, a damage to the original paint system or to change the car color. The split of plastic in paint between OEM and Refinish is taken from Hann et. al, 2018, Table 60.

3. LOSSES

Losses	Uses	Loss rates	Uncertainty	Notes
Unused	Automotive OEM	3%	low	[1]
Unused	Automotive Refinish	3%	low	[1]
Application	Automotive OEM	10%	medium	[2]
Application	Automotive Refinish	40%	high	[3]
Wear & Tear	Automotive OEM	2%	medium	[4]
Wear & Tear	Automotive Refinish	2%	medium	[4]

Losses parameters	Uses	Value	Uncertainty	Notes
Removal factor	Automotive OEM	10	medium	[5]
Removal factor	Automotive Refinish	10	medium	[5]

[1] See note [1] in Losses table of Architectural paint Appendix

[2] The Automotive OEM paint is made of multiple layers: one layer of electro-paint (15 microns, applied by catapheratic bath, 2% losses), one layer of primer surfacer (30 microns, applied with electrostatic spray, 10% losses), a base coat layer (10 microns, applied through spray, 10-40% losses), and a clear coat layer (30 microns, electrostatic spray, 10% losses). By assuming that the polymer content is similar across layers, we have an overall loss rate at application of 10.35%. This insight was gather in an interview with an automotive paint expert.

[3] According to *OECD, 2009*, around 15% of the plastic in Refinish paint will be lost as equipment residue during spraying, while another 51.5% will be lost due to overspray. We reduce the amount losses due to overspray to 25% to account for technological improvement that might have led to a higher transfer efficiency and a reduction in losses at application.

[4] The Wear & Tear losses include flaking and chipping of the paint due to weathering (such as exposure to ultra-violet sun rays), but also due to accidents and collisions. According to an interview with an automotive paint expert these types of losses are minimal. Therefore, we assume a 2% loss rate even though according to OECD, 2009 flaking and chipping losses of automotive paint are quantified at 10% (after rescaling by the OECD application losses).

[5] We assume that when some paint is lost due to weathering or an accident, the entire car panel undergoes paint removal and repainting. For this reason we choose a high removal factor of 10.

Losses	Uses	Soil	Road	Solid waste	Waste water	Special waste	Autom. Waste	*Tot*	Uncertainty	Notes
Unused	Automotive OEM					100%		*100%*	high	[1]
Unused	Automotive Refinish			5%		95%		*100%*	high	[2]
Application	Automotive OEM					100%		*100%*	none	[1]
Application	Automotive Refinish	6%		92%	3%			*100%*	low	[3]
Wear & Tear	Automotive OEM		100%					*100%*	none	[4]
Wear & Tear	Automotive Refinish		100%					*100%*	none	[4]
Removal	Automotive OEM			100%				*100%*	none	[5]
Removal	Automotive Refinish			100%				*100%*	none	[5]
EOL	Automotive OEM						100%	*100%*	none	[6]
EOL	Automotive Refinish						100%	*100%*	none	[6]

4. PATHWAYS

[1] We assume that the Unused paint and the paint lost during the application process of OEM paint at the manufacturing plant, will be disposed of as special waste in the country were the manufacturing takes place (see Regions table below).

[2] See note [1] in Pathways table of Architectural paint Appendix

[3] The pathways of application losses of Refinish paint are based on OECD, 2009.

[4] We assume that the paint lost due to flaking and chipping will be lost on road.

[5] Paint removed at repaint will be disposed in the body shop as waste. Lacking better insight on the waste management of body shops around the world, we assume that whether they dispose of the waste properly or improperly is going to correlate with the general country solid waste management, and therefore we assign it to this same pathway.

[6] The paint left on the automotive vehicle until its end of life will be disposed together with it. We did not perform an analysis on the fate of automotive vehicles, on recycling or re-use practices. This would be needed to have a better understanding of the probable fates of paint from the "Automotive waste" pathway. In this analysis, fates of solid waste will be use to determine the fates of automotive waste.

5. REGIONS

Vehicles manufacturing

Region - Income	Shares	Uncertainty	Notes
Europe - High Income	19%	low	[1]
Europe - Lower Income	3%	low	[1]
MEA - High Income	0%	low	[1]
MEA - Lower Income	4%	low	[1]
Asia-Pacific - High Income	15%	low	[1]
Asia-Pacific - Lower Income	38%	low	[1]
Latin America - High Income	0%	low	[1]
Latin America - Lower Income	3%	low	[1]
North America - High Income	14%	low	[1]
North America - Lower Income	4%	low	[1]
Tot	*100%*		

[1] The table shows the shares of motor vehicles manufacturing by region in 2019, as provided by OICA, 2022. These shares are used to determine the geographical distribution of Unused and Application paint losses of OEM paint.

Vehicles use

Region - Income	Shares	Uncertainty	Notes
Europe - High Income	24%	medium	[2]
Europe - Lower Income	6%	medium	[2]
MEA - High Income	2%	medium	[2]
MEA - Lower Income	6%	medium	[2]
Asia-Pacific - High Income	11%	medium	[2]
Asia-Pacific - Lower Income	17%	medium	[2]
Latin America - High Income	2%	medium	[2]
Latin America - Lower Income	6%	medium	[2]
North America - High Income	24%	medium	[2]
North America - Lower Income	3%	medium	[2]
Tot	*100%*		

[2] Computation based on dataset of motor Vehicles per 1000 people by country. The data set is published on OurWorldInData, 2014, which cites NationMaster, 2014 as source, but the original data come from a wikipedia page that compiles these values from several national level sources (Wikipedia, 2021). Although the repair practices of damaged vehicles may depend on factors such has the country income level or the country regulation, we assume that maintenance work as well as wear & tear and EOL losses will be proportional to the number of vechicles by country.

SECTION

4.6

APPENDIX

INDUSTRIAL WOOD

1. Paint Demand
2. Losses
3. Regions
4. Pathways
5. Fates

INDUSTRIAL WOOD

1. PAINT DEMAND

Sector	Plastic content 2019 kt	Uncertainty	Notes
Industrial Wood	1232	low	[1]

[1] MarketsandMarkets Research Private Limited

2. LOSSES

Losses	Loss rates	Uncertainty	Notes
Unused	3%	low	[1]
Application	52%	high	[2]
Wear & Tear	0%	none	[3]

[1] See note [1] in Losses table of Architectural paint Appendix

[2] Taken from *OECD, 2009* analysis of the wood furniture sector, which models the loss rates at application when using a dry booth. Other techniques are wet booth or curtain coating.

[3] Although a small fraction of the paint applied to wooden furniture is lost due to wear & tear, and most likely results in household dust. *OECD, 2009* does not propose an estimate for these losses and we consider them negligible.

3. REGIONS

Region - Income	Shares	Uncertainty	Notes
Europe - High Income	19%	medium	[1]
Europe - Lower Income	8%	medium	[1]
MEA - High Income	0%	medium	[1]
MEA - Lower Income	5%	medium	[1]
Asia-Pacific - High Income	5%	medium	[1]
Asia-Pacific - Lower Income	37%	medium	[1]
Latin America - High Income	2%	medium	[1]
Latin America - Lower Income	3%	medium	[1]
North America - High Income	20%	medium	[1]
North America - Lower Income	1%	medium	[1]
Tot	*100%*		

[1] The shares by regions are determined based on the wood consumption by country. FAO online database "Forestry Production and Trade" (*FAO, 2021*) allows to select specific wood application and track their production and trade around the world. The applications selected for this study are: hardboard, MDF/HDF, OSB, other fiberboard, particle board, plywood, sawn wood, veneer sheets. The reference year is 2019. Since losses for industrial wood paint are linked both to application of paint and to the EOL of the coated wood, we computed both the shares of production and of consumption by region and income. The two sets of shares were very similar to each others (average discrepancy by region = 1.4%), therefore we chose the average between the two sets of shares to estimate the distribution of industrial wood paint by region and income.

4. PATHWAYS

Losses	Special waste	Solid waste	Recycling	*Tot*	Uncertainty	Notes
Unused	95%	5%	0%	*100%*	high	[1]
Application	0%	100%	0%	*100%*	none	[2]
EOL	0%	50%	50%	*100%*	high	[3]

[1] See note [1] in Pathways table of Architectural paint Appendix

[2] Based on *OECD, 2009* analysis for the Wood furniture sector

[3] Painted or varnished wood is sometimes considered recyclable in order to produce wood chippings for plywood or particle board, while in certain contexts, regulation requires painted wood to be disposed as waste. See for example the waste management guidelines for the city of Lausanne (*Ville de Lausanne, 2021*).
We assume that of the paint that was left on the wood until its end of life, 50% will follow the wood during its recycling process and the other 50% will be disposed as waste.

5. FATES

Fates of recycling pathway

Region - Income	Leaked to Ocean & Waterways	Well managed	Leaked to Land	Embedded in new products	Uncertainty	Notes
Europe - High Income	3%	5%	23%	70%	high	[1]
Europe - Lower Income	3%	5%	23%	70%	high	[1]
MEA - High Income	3%	5%	23%	70%	high	[1]
MEA - Lower Income	3%	5%	23%	70%	high	[1]
Asia-Pacific - High Income	3%	5%	23%	70%	high	[1]
Asia-Pacific - Lower Income	3%	5%	23%	70%	high	[1]
Latin America - High Income	3%	5%	23%	70%	high	[1]
Latin America - Lower Income	3%	5%	23%	70%	high	[1]
North America - High Income	3%	5%	23%	70%	high	[1]
North America - Lower Income	3%	5%	23%	70%	high	[1]

[1] In note [1] of Fates table in Architectural appendix, see fates of recycling "exterior - wood".

A WORD FROM Pinovo

In June, 2020, Pinovo's clean circular vacuum blasting technology was one of the Finalists in the UpLink Ocean Solution Sprint, a competition organized by UpLink, the open digital platform set up by WEF (World Economic Forum) to accelerate progress in achieving the United Nation's SDG's. Pinovo's solution stops paint microplastic emissions from surface maintenance being released into the environment.

In seeking to quantify the impact of Pinovo's technology on SDG14, Life Below Water, it became clear that there was insufficient data available on the global level of Paint Microplastic Leakage. The 2014 Mepex report for the Norwegian Environment Agency had identified Paint as being the second most important source of Microplastics in the Norwegian Ocean. Subsequent studies, including the Eunomia report for the EU Commission in 2018, "salami sliced" the issue by only looking at the leakage from selected paint applications e.g. road markings, marine paint, etc., without addressing the overall issue.

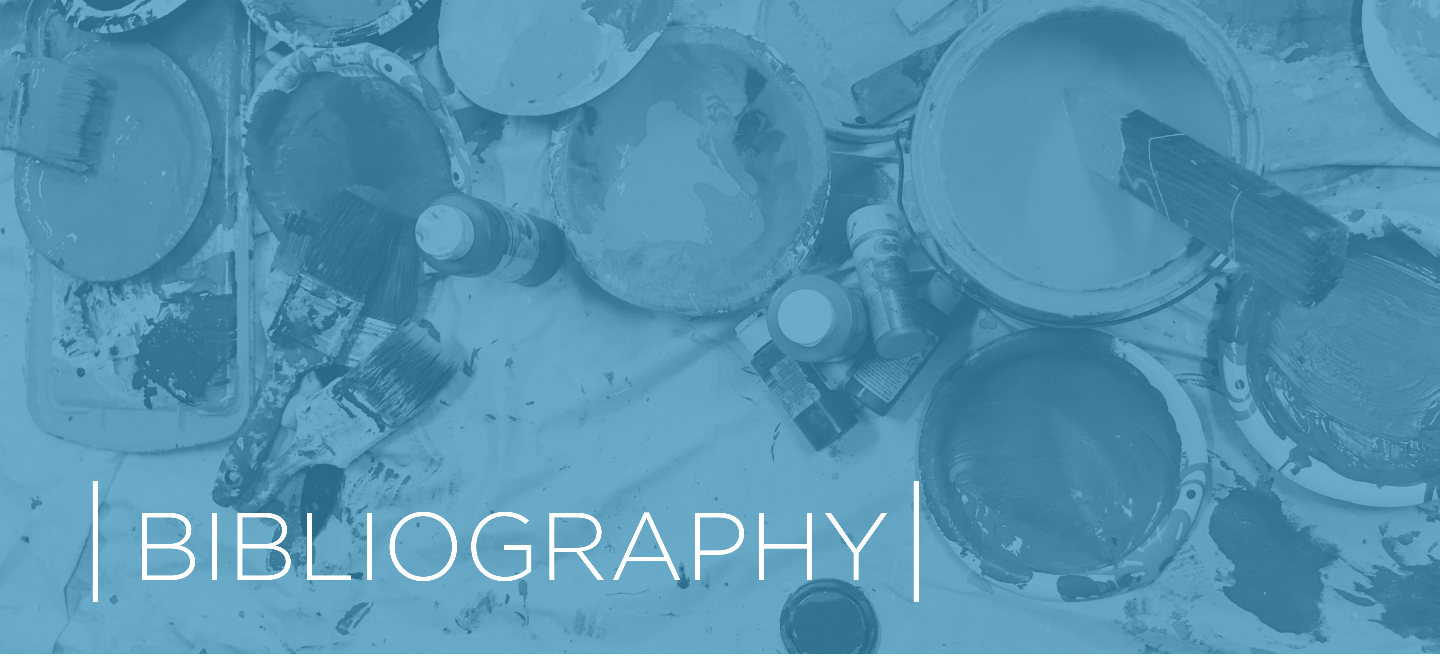
In addition, assumptions were made about the speed of paint degradation, etc. that have since been called into question.

With the aim of shedding more light on global Paint Microplastic Leakage, Pinovo decided to mandate independent scientific research on the issue. We sought advice from IUCN (The International Union for the Conservation of Nature), leaders in the research of microplastics who had previously identified the scale of Microplastic Leakage from tyres, as to the best team to undertake this work. They recommended EA (Environmental Action), world leaders in this field of scientific research, who had authored several reports on microplastics.

We welcome the EA report that shows clearly the real scale of Global Paint Microplastic Leakage. We hope that it will encourage regulators at a national and transnational level, including the EU Commission, to address this issue. That in turn should drive regulatory change and enforcement. The solutions adopted will also help the EU Commission achieve its laudable objective of reducing microplastics in the environment by 30% before 2030.

We hope that the EA report will lead to more scientific research into the whole area of Microplastic Leakage to the Ocean, including water sampling in different regions around the world to identify "hot spots", and the impact on human health of those Microplastics entering the food chain via plankton, fish, shellfish, etc. We also look forward to engagement of the Paint Industry, and their surface maintenance customers, on this important issue, and their adoption of solutions to stop Paint Microplastic Leakage.

Declan Mc Adams - chairman
Pinovo AS, Bergen, Norway



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