

**ENVIRONMENT DIRECTORATE**

**Monitoring trade in plastic waste and scrap (2024)**

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Keywords: Plastics, Trade, Circular economy, Waste management

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# Abstract

Global trade in plastic waste and scrap declined further (2017-2022) in 2022. The combined trade surplus of OECD Member Countries (i.e., the difference between exports and imports) continued to decrease. Less plastic waste and scrap is being exported by OECD countries to non-OECD countries, however some countries still export substantial volumes to non-OECD countries. Particularly several non-OECD south-east Asian countries remain large export destinations. Trade between OECD countries has increased. The value and composition of plastic waste and scrap exports in 2021 suggests that more high value and easy to recycle plastic waste was traded. Some volume of plastics waste is likely transformed into a “fuel” via mechanical and chemical processing and subsequently shipped as Processed Engineered Fuel (PEF) or Refuse-Derived Fuels (RDF), broadly categorised under HS 3825. There was an increase in this trade mostly between OECD countries in 2021. The trade regime remains dynamic with new export destinations emerging, which deserve further monitoring.

**Keywords:** plastics, trade, circular economy, waste management

**JEL Codes :** F18, L65, Q53, Q56

# Résumé

Le commerce mondial des déchets et débris plastiques a encore diminué (2017-2022) en 2022. L'excédent commercial combiné des pays membres de l'OCDE (c'est-à-dire la différence entre les exportations et les importations) a continué à diminuer. Les pays de l'OCDE exportent moins de déchets et débris de plastique vers les pays non-membres de l'OCDE, mais certains pays continuent d'exporter des volumes importants vers les pays non-membres de l'OCDE. En particulier, plusieurs pays d'Asie du Sud-Est non membres de l'OCDE restent d'importantes destinations d'exportation. Les échanges entre les pays de l'OCDE ont augmenté. La valeur et la composition des exportations de déchets et débris de matières plastiques en 2021 suggèrent que davantage de déchets plastiques de grande valeur et faciles à recycler ont été échangés. Un certain volume de déchets plastiques est probablement transformé en "combustible" par un traitement mécanique et chimique, puis expédié en tant que "Processed Engineered Fuel" (PEF) ou "Refuse-Derived Fuels" (RDF), classés dans la catégorie générale du SH 3825. Ce commerce a augmenté, principalement entre les pays de l'OCDE en 2021. Le régime commercial reste dynamique et de nouvelles destinations d'exportation apparaissent, qui méritent d'être suivies de plus près.

**Mots clés :** Plastiques, commerce, économie circulaire, gestion des déchets

**Classification JEL :** F18, L65, Q53, Q56

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# Table of contents

Abstract	3
Résumé	4
Acknowledgements	5
Executive Summary	7
1 Introduction	9
2 Results and discussion	11
2.1. Global trade in plastic waste and scrap declined (2017-2022)	11
2.2. OECD's trade balance is increasingly shifting from being export-oriented to having a more neutral trade balance	13
3 References	29
Annex A. Methodology	31
<b>Tables</b>	
Table 2.1. Most reported plastics waste exports by OECD countries subject to PIC were destined for other OECD countries in 2021	25
<b>Figures</b>	
Figure 2.1. Global plastic waste and scrap by export destination type	12
Figure 2.2. Key importers of plastic waste and scrap globally	13
Figure 2.3. OECD export and import developments and their share in global trade	14
Figure 2.4. 2021 and 2022 exports by OECD member countries	15
Figure 2.5. Comparison of annual export volumes between 2021 and 2022	15
Figure 2.6. 2022 exports by OECD countries globally	16
Figure 2.7. Global trade flows in plastic waste and scrap	17
Figure 2.8. Key destinations of OECD exports of plastic waste and scrap	18
Figure 2.9. 2021 and 2022 imports by OECD member countries	20
Figure 2.10. Comparison of annual import volumes between 2021 and 2022	20
Figure 2.11. Trade value per volume of exports of plastic waste and scrap by OECD member countries	22
Figure 2.12. OECD plastic waste and scrap exports by commodity type	23
Figure 2.13. OECD exports of vinyl chloride wastes and scrap	24
Figure 2.14. OECD and non-OECD trade flow developments for HS 3825	27
<b>Boxes</b>	
Box 1.1. Overview of recent policy developments	10
Box 2.1. Relevant work published or underway	28

# Executive Summary

1. This paper is the fourth in a series of monitoring reports to assess the impact of new international controls on transboundary movement of plastic waste and scrap. Prior to 2018, the People's Republic of China (hereafter China) and Hong Kong, China (hereafter Hong Kong) together received a large share of the trade in plastic waste and scrap. This declined with the advent of China's "National Sword" policy that tightened national import restrictions and led to a reduction in imports from 2018 onwards. Two new sets of multilateral controls took effect in 2021. These were amendments at the Basel Convention and changes to the OECD Decision on Transboundary Movement of Waste. This report is the first in the series to analyse annual data for 2022. This new data offers further insights in the medium to long term impacts of the new controls for plastic waste shipments.

## Global trade in plastic waste and scrap is declining

2. Annual reported global export volume of plastic scrap and waste declined by almost half (49%) over the past six years, from around 12.4 million metric tonnes (megatonnes, Mt) in 2017 to 6.3 Mt in 2022. The decrease was slightly steeper between 2021 and 2022 compared to 2020 and 2021. Global export volumes declined by 4.9% between 2021 and 2022 (6.7 Mt to 6.3 Mt) compared with a 1.9% decrease between 2020 and 2021 (6.8 Mt to 6.7 Mt). The share of trade among OECD member countries grew, especially within geographic regions. For example, trade within Europe and North America now makes a larger share than exports from these regions to other parts of the world.

## Southeast Asia remains a key export destination

3. Non-OECD countries in South and Southeast Asia continue to receive large volumes. Malaysia was the second largest export destination for all trade globally in 2022. Viet Nam was fourth. Indonesia was tenth. Notably, Indonesia saw a 26% increase in imports in 2022 compared to 2021. Japan, the United States, the Netherlands, and Germany were the OECD countries that exported the largest volumes to non-OECD countries.

## OECD countries are transitioning from export dependence to a balance of trade

4. The difference between exports and imports of plastic waste and scrap by OECD member countries nearly disappeared and amounted to only 0.2 Mt in 2022. OECD countries accounted for 87% of total global exports, and 77% of total global imports.

## Exports from OECD to non-OECD countries appear to be of lower quality

5. This report uses a metric for material quality (value per kg of traded plastic waste and scrap). The value of this metric for both intra-OECD trade and OECD to non-OECD trade reached six-year highs in early 2022 with a value of 0.69 USD/kg for intra-OECD trade, and 0.55 USD/kg for OECD to non-OECD trade. Whilst both values converged, intra-OECD trade was consistently a higher value. The rise in trade values could have stemmed from a general increase in commodity and resin prices from 2021 to mid-2022, due to rising costs of primary feedstocks (e.g., crude oil and naphtha). Both values declined in the second half of 2022. A similar decline occurred with falling commodity prices. This suggests that the value of the waste and scrap trade followed price changes in primary equivalent.

## The composition of plastic waste traded did not change

6. Countries report trade at a more detailed level, known as six-digit HS codes. This level of data enables analysis on the composition of waste trade. The share of trade in “ethylene polymers” (HS 391510) decreased marginally by one percentage point, whereas the share of “styrene polymers” (HS 391520) increased by one percent. Exports of “vinyl chloride polymers” (HS 391530) are subject to Basel controls that require prior informed consent. The share of this trade has fallen and is mostly traded among OECD and EU countries. But trade outside the OECD reportedly persists.

## The reported share of plastics subject to prior informed consent is small.

7. This monitoring report compares the data submitted by OECD countries to UN Comtrade and in the national reports to the Basel Convention Secretariat for the first time in this series. Countries report all plastic waste and scrap trade to UN Comtrade, but they need only report waste subject to the prior informed consent (PIC) procedure in national reports to the Basel Convention Secretariat. Amendments to Annexes II, VIII and IX took effect in 2021, meaning that countries should be reporting data about trade subject to PIC in 2021 and 2022 in their national submissions. According to data reported by Basel parties for 2021, the total amount of plastic waste exported by OECD countries subject to the PIC procedure was 17 193 tonnes. This is small compared to UN Comtrade data submissions. This suggests that OECD countries are not yet systematically reporting the plastics waste trade subject to PIC procedure.

## Plastic waste and scrap are traded under HS codes other than 3915

8. National governments and environmental non-governmental organisations have raised concern that the reported trade in HS code 3915 does not capture all trade in plastic waste and scrap. Additional trade could include, among others, waste containing plastic that is transformed into a “fuel” via mechanical and chemical processing and subsequently shipped as Processed Engineered Fuel (PEF) or Refuse-Derived Fuels (RDF), broadly categorised under HS 3825.

9. There was an increase in trade volumes of HS 3825 in 2021. Non-EU OECD European countries were responsible for most of that increase in exports and most of their exports were to OECD EU countries. While OECD countries in Europe—most with advanced systems for waste recovery—are responsible for a vast majority of exports and imports in this type of waste, this trade in plastic waste for energy recovery is legal and not controlled at present. In addition, global capacity for waste-to-energy is growing. Future monitoring reports will continue to evaluate trends in this trade.



# 1 Introduction

10. Trade in plastic waste is a key point in policy efforts to end plastic waste leakage to the environment. Proponents argue that international trade in plastic waste and scrap enables the movement of materials to countries with a comparative advantage in recycling plastic and thus plays a key role in strengthening secondary plastics markets. However, export destinations have also experienced an influx of plastic waste and scrap that was in part hazardous or heavily contaminated. This raised concerns both about quality and the capacity of receiving countries to manage this waste in an environmentally sound manner (OECD, 2022<sup>[1]</sup>; Brown, Laubinger and Börkey, 2023<sup>[2]</sup>).

11. This paper is the fourth in a series of monitoring reports to assess the impact of new international controls on plastic waste and scrap.<sup>1</sup> Two new sets of controls took effect in 2021. These were amendments at the Basel Convention and changes to the OECD Decision on Transboundary Movement of Waste.

12. The report is built upon analysis of UN Comtrade data and party submissions to the Basel Convention Secretariat. The authors extracted UN Comtrade data<sup>2</sup> on 13 October 2023. The methodology used is the same as previous reports (see Annex A).

13. This trade flow analysis considers the following HS Codes:

- HS 3915: Waste, parings and scrap, of plastics
  - HS 391510: Ethylene polymers waste, parings and scrap;
  - HS 391520: Styrene polymers waste, parings and scrap;
  - HS 391530: Vinyl chloride polymers waste, parings and scrap; and
  - HS 391590: plastics not elsewhere classified (n.e.c.), a catch-all for other material.

14. Stakeholders have identified that trade in plastic waste and scrap is occurring outside of HS 3915. For example some plastic waste is traded as Refuse-derived fuel (RDF). For the first time in this series, the authors analysed trade flow of the relevant 4-digit HS code 3825:

- HS 3825: Residual products of the chemical or allied industries, not elsewhere specified or included; municipal waste; sewage sludge; other residual products.

15. This report makes use of annual data submissions from 2017 to 2022 throughout for the analysis of global trade patterns. Monthly data from January to November 2022 informs computation of a trade value indicator. Data for 2023 as well as December 2022 were incomplete and thus excluded in this analysis.

16. This continues the assessment of the longer-term consequences of new international controls at the level of the *Basel Convention on the Control of Transboundary Movements of Wastes* (hereafter: the Basel Convention) and the *OECD Decision of the Council on the Control of Transboundary Movements of*

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<sup>1</sup> It continues and builds upon the last monitoring report (Brown, Laubinger and Börkey, 2023<sup>[2]</sup>)

<sup>2</sup> UN Comtrade is a database that aggregates detailed global annual and monthly trade statistics based on the Harmonised Code (HS) nomenclature, which classifies goods based on a 6- digit code system.

*Wastes Destined for Recovery* (hereafter: the OECD Decision), which both entered into force on 1 January 2021 (Box 1.1).

### Box 1.1. Overview of recent policy developments

Recent policies have increasingly controlled trade in plastic scrap and waste, owing to mounting environmental concerns related to the lack of environmentally sound management of plastic waste and scrap in export destination countries.

At the international level, the 14th meeting of the Conference of the Parties (COP) to the Basel Convention adopted amendments to Annexes II, VIII and IX to the Basel Convention relating to plastic waste and scrap. The amendments control the transboundary movement of certain plastic waste and scrap and entered effect on 1 January 2021 (Secretariat of the Basel Convention, 2019<sup>[3]</sup>).

The OECD Decision of the Council on the Control of Transboundary Movements of Wastes Destined for Recovery Operations [OECD-LEGAL-0266], which is closely interlinked with the Basel Convention, was also amended (OECD, 2020<sup>[4]</sup>). As of 1 January 2021, the following rules apply:

- Hazardous plastic waste and scrap, namely those covered by new Basel entry A3210, will be subject to the Amber control procedure under the OECD Decision and listed as new OECD entry AC300<sup>3</sup> under Appendix 4, Part II. This means that countries will need to control movement of such waste and scrap pursuant to the tacit consent procedure with a consideration period of 30 days, or seven days where pre-consented facilities are concerned.
- For other plastic waste and scrap, namely those covered by new Basel entries B3011 and Y48, each OECD Member country retains its right to control the plastic waste and scrap in question in conformity with its domestic legislation and international law. The OECD maintains a public website with the known controls taken by OECD Member Countries with regards to transboundary movements of non-hazardous plastic waste and scrap.<sup>4</sup>

OECD Member Countries have adopted different controls for transboundary movements of non-hazardous plastic waste. Bilateral or regional agreements or arrangements exist between the United States and Canada and within the EU single market, leaving this intra-regional trade unencumbered.

Countries have implemented unilateral restrictions. Notably, Türkiye temporarily banned the import of HS 391510 ethylene polymers waste and scrap in July 2021, but subsequently replaced the ban with an enhanced licensing system (Staub, 2021<sup>[5]</sup>).

Source: adapted from (Brown, Laubinger and Börkey, 2023<sup>[2]</sup>)

<sup>3</sup> The new OECD entry AC300 corresponds to Basel entry A3210. Transport of hazardous waste within the OECD, should be under AC300.

<sup>4</sup> An up-to-date table of national controls is available here: <https://www.oecd.org/environment/waste/Reporting-of-controls-non-hazardous-waste.pdf>

# 2 Results and discussion

## 2.1. Global trade in plastic waste and scrap declined (2017-2022)

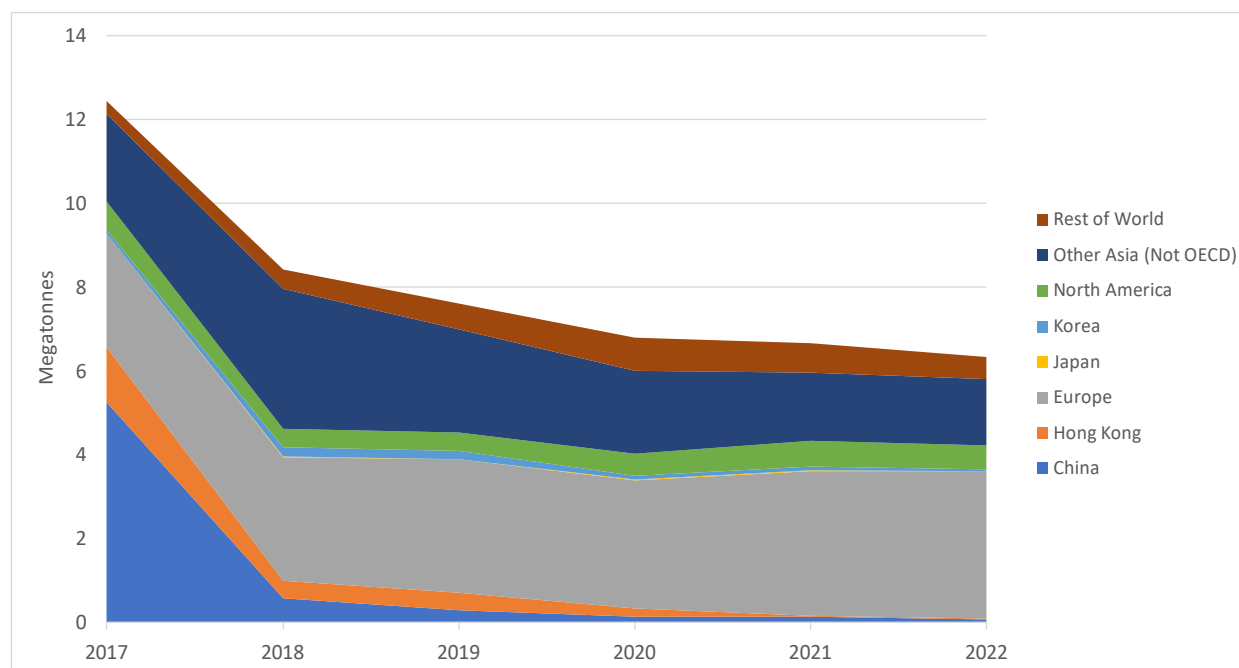
17. Annual reported global export volume of plastic scrap and waste declined by almost half (49%) over the past six years, from around 12.4 million metric tonnes (megatonnes, Mt) in 2017 to 6.3 Mt in 2022. The decrease was slightly steeper between 2022 and 2021 compared to 2021 and 2020. Global export volumes declined by 4.9% between 2021 and 2022 (6.7 Mt to 6.3 Mt) compared with a 1.9% decrease between 2020 and 2021 (6.8 Mt to 6.7 Mt). This may be a result of countries further adjusting to the new international trade rules (see Box 1.1).

18. Prior to 2018, the People's Republic of China (hereafter China) and Hong Kong, China (hereafter Hong Kong) together received a large share of the trade in plastic waste and scrap. This declined with the advent of China's "National Sword" policy that tightened national import restrictions and led to a reduction in imports from 2018 onwards. In 2022, exports to China and Hong Kong amounted to only 1.1% (0.07 Mt) of the global volume traded (Figure 2.1).

19. The share of total plastic waste and scrap destined for "Other Asia" (which includes non-OECD countries in South and Southeast Asia) rose sharply in late 2017 and 2018 but steadily declined since 2019, reaching 1.6 Mt in 2022. In contrast, the share of plastic waste exported to European countries, which also includes intra-EU trade, has increased steadily, by 0.4 Mt from 2020 to 2022 (or a 15% increase), to reach 3.5 Mt in 2022 (Figure 2.1).

**Figure 2.1. Global plastic waste and scrap by export destination type**

Reported annual export volume of HS 3915 (Waste, parings and scrap, of plastics) by destination type (2017-2022)



Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

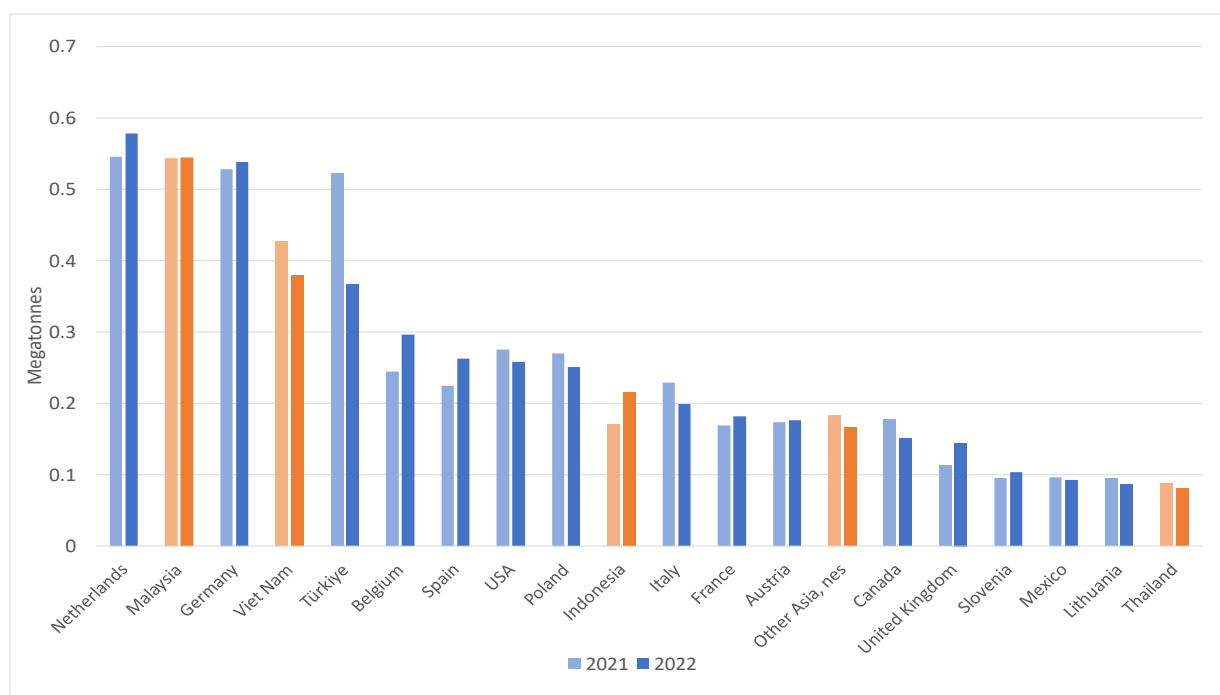
20. Imports<sup>5</sup> by non-OECD countries declined by 9% between 2021 and 2022, from 2.2 Mt to 2.0 Mt. However, non-OECD countries, notably in the Southeast Asia region, remain among the largest importers of plastic waste and scrap. The Netherlands, followed by Malaysia and Germany remained the largest importer of plastic waste and scrap in 2022, as in 2021. The largest decrease in imports experienced Türkiye (in absolute volume), likely because of tightened national controls (see Box 1.1). Imports for non-OECD countries including Viet Nam, “Other Asia nes”<sup>6</sup> and Thailand declined compared to 2021, whilst imports to Indonesia rose by 26% over the same period (Figure 2.2).

<sup>5</sup> This report uses export data by destination to generate import figures, because this data tends to be more complete in UN Comtrade.

<sup>6</sup> Other Asia, nes (“not elsewhere specified”) includes, *inter alia*, exports to Chinese Taipei.

**Figure 2.2. Key importers of plastic waste and scrap globally**

Reported annual export volume of HS 3915 (Waste, parings and scrap, of plastics) volume destined to key importers



Note: **Blue** = OECD countries; **Orange** = non-OECD countries; Other Asia, nes (“not elsewhere specified”) includes, *inter alia*, exports to Chinese Taipei.

Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

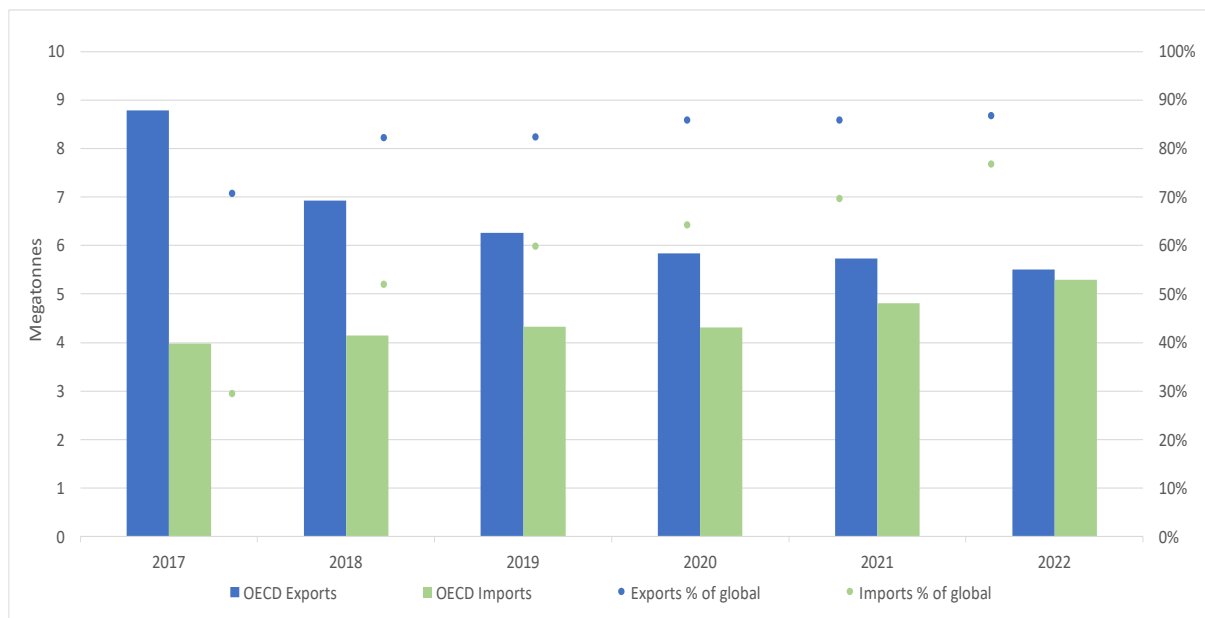
## 2.2. OECD’s trade balance is increasingly shifting from being export-oriented to having a more neutral trade balance

21. In 2022, the trend of a declining trade balance continued with OECD member countries shifting from being net exporters to having a neutral trade balance. Exports from OECD countries continued to decrease, whereas imports by OECD countries increased and were level in 2022.

22. The share of OECD exports in total global volume remained stable, with a slight increase from 86% in 2021 to 87% in 2022. OECD imports as a share of global imported volumes increased by 7%, from 70% in 2021 to 77% in 2022. A similar trend was visible in terms of absolute volumes, where OECD exports decreased slightly by 0.2 Mt (or by 4%), reaching 5.5 Mt in 2022, in line with global trends, whilst OECD imports grew by 0.5 Mt, to reach 5.3 Mt (Figure 2.3).

**Figure 2.3. OECD export and import developments and their share in global trade**

Annual import and export of HS 3915 (Waste, parings and scrap, of plastics) reported by OECD member countries (net volume and share of global volume)



Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

### **Exports by OECD countries**

23. In 2022, the top five OECD exporters were Germany, the Netherlands, Japan, USA, and Belgium. Exports declined for twenty OECD countries in 2022 compared to 2021, whilst exports increased for eighteen (

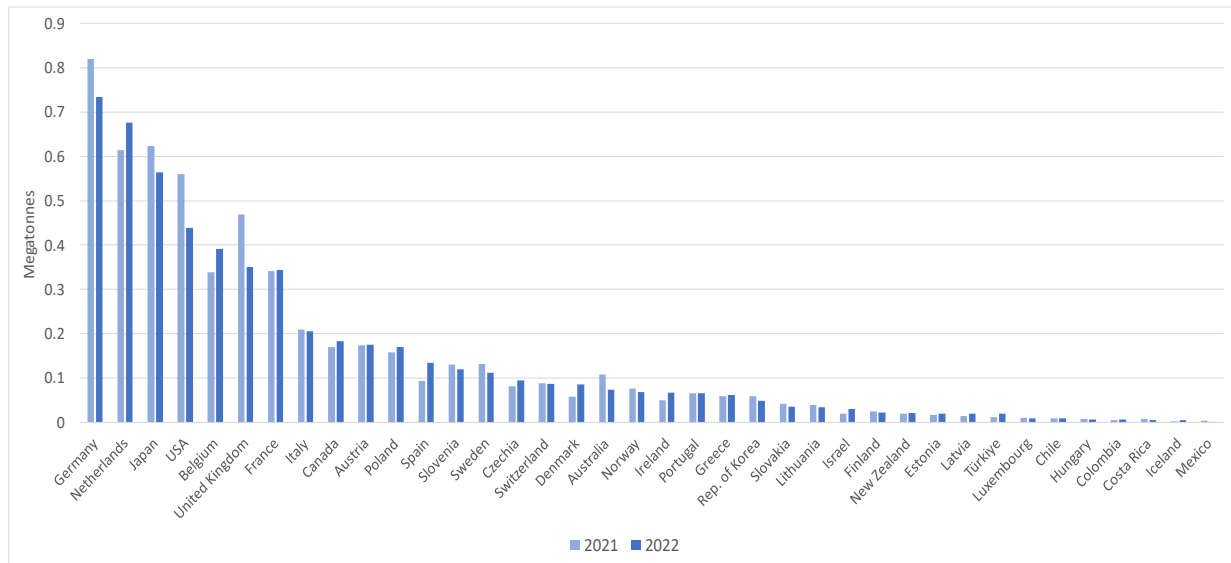
24. Figure 2.4).

25. The United Kingdom experienced the largest decline in exports (a decline of 0.12 Mt, or 25%) with total exports amounting to 0.35 Mt, the United States' (a decline of 0.12 Mt, or 22%) amounting to 0.44 Mt, and Germany (a decline of 0.09 Mt, or 10%) amounting to 0.73 Mt.

26. The largest increases in exports were observed in Spain (an increase of 0.04 Mt, or 43%) amounting to 0.13 Mt, Belgium (and increase of 0.05 Mt, or 16%) amounting to 0.39 Mt, and the Netherlands (an increase of 0.06 Mt, or 10%) amounting to 0.68 Mt (Figure 2.5).

**Figure 2.4. 2021 and 2022 exports by OECD member countries**

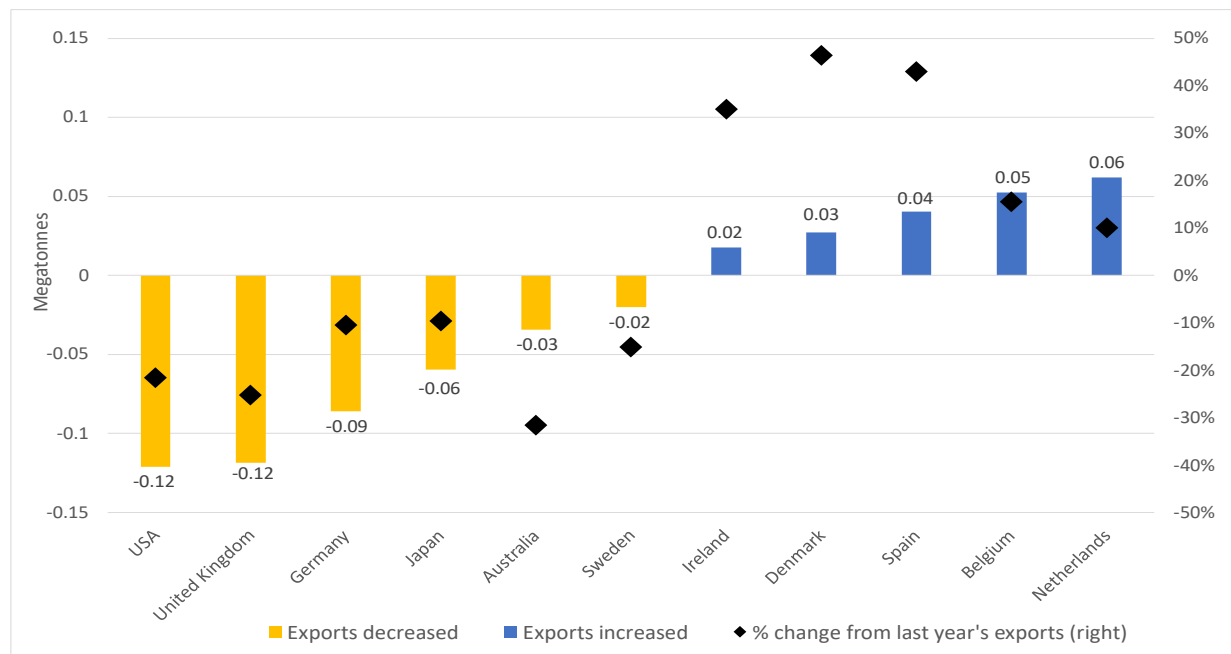
Reported annual export volume of HS 3915 (Waste, parings and scrap, of plastics) by OECD member country



Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.[6])

**Figure 2.5. Comparison of annual export volumes between 2021 and 2022**

Difference in annual export volumes of HS 3915 (Waste, parings and scrap, of plastics) by OECD member country



Note: Includes only OECD countries with an annual absolute difference in exports of 0.02 Mt or above.

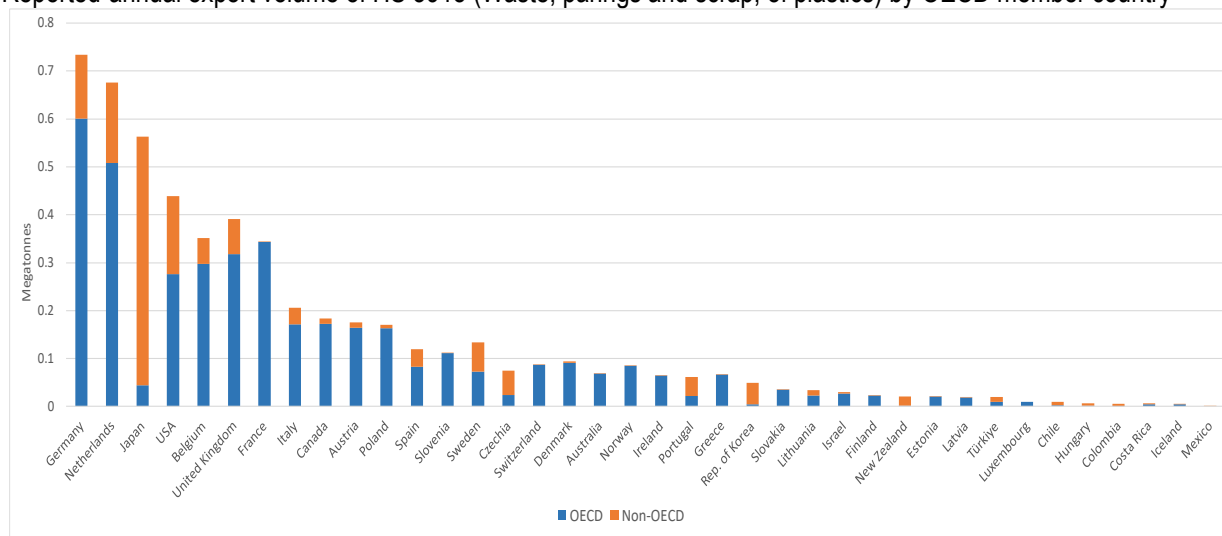
Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.[6])

27. The volume of OECD exports to non-OECD countries declined by 7% (by 0.11 Mt), from 1.6 Mt in 2021 to 1.4 Mt in 2022. The share of OECD exports to non-OECD countries remained the same: 27% in 2022 and 28% in 2021.

28. Japan remains the OECD country that exported the most in absolute volume to non-OECD countries (0.52 Mt, 92% of their exports), followed by the Netherlands (0.17 Mt, 25%), the US (0.16 Mt, 37%), Germany (0.13 Mt, 18%) and Belgium (0.07 Mt, 19%) (Figure 2.6).

**Figure 2.6. 2022 exports by OECD countries globally**

Reported annual export volume of HS 3915 (Waste, parings and scrap, of plastics) by OECD member country



Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

29. The trade flow developments in 2022 for the largest OECD exporters include:

- **Germany:** The largest trading partners for Germany were OECD countries, e.g., the Netherlands, Türkiye, and Poland. Overall exports from Germany declined by 10% from 0.82 Mt in 2021 to 0.73 Mt in 2022, but exports have risen for certain non-OECD countries. Exports to Malaysia grew by 32% to reach 0.07 Mt, making Malaysia Germany's fourth-largest trading partner. Exports to Indonesia increased seven-fold compared to 2021, to reach 0.03 Mt, making Indonesia Germany's eighth-largest trading partner.
- **The Netherlands:** Exports increased by 10% from 0.61 Mt in 2021 to 0.67 Mt in 2022. Belgium and Germany remained the largest export destinations, followed by Indonesia. Growing export destinations include Türkiye (54% increase, to reach 0.04 Mt), Spain (increase by a factor of 4.5, reaching 0.03 Mt) and Indonesia (21 % increase, reaching 0.09 Mt). Exports to Viet Nam and Malaysia declined by 46% and 33% respectively, reaching 0.03 Mt for both.
- **Japan:** Overall exports declined by 10% from 0.62 Mt in 2021 to 0.56 Mt in 2022. Japan's exports were mostly sent to non-OECD countries. Malaysia, Viet Nam, "Other Asia, nes," Thailand, and Republic of Korea were its top five trading partners in 2022, followed by Indonesia, Hong Kong, India, USA, and the Philippines. While exports to its top five destinations all declined this year, Japan's exports to Indonesia, India, and USA rose by 14%, 53%, and 24% respectively.
- **United States:** Overall exports declined by 22% from 0.56 Mt in 2021 to 0.44 Mt in 2022. Most US exports were destined to its neighbours Canada and Mexico, as was the case in 2021. Exports to Malaysia, Indonesia, and Viet Nam have declined compared to 2021 (by 57%, 26%, and 59% respectively, to reach 0.04 Mt, 0.02 Mt, and 0.01 Mt in volume). More trade is taking place with



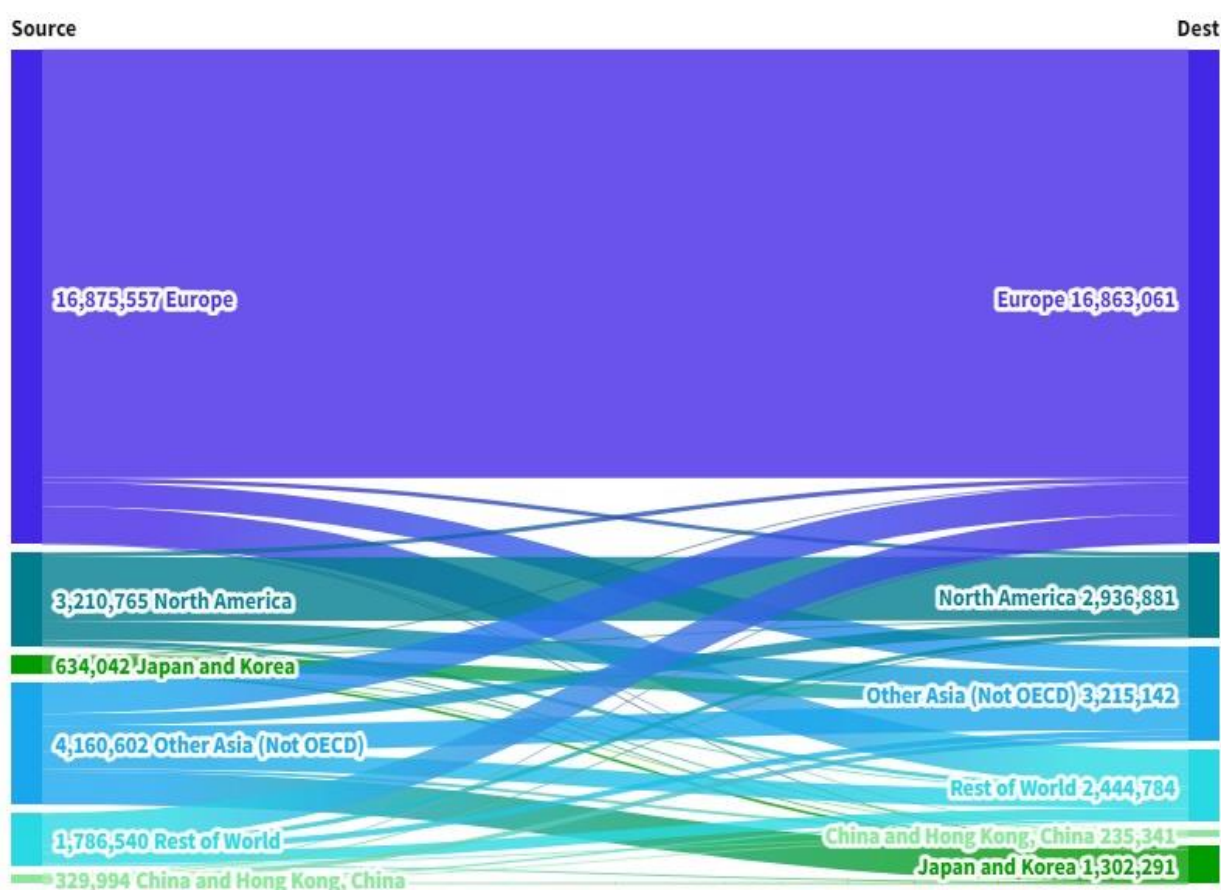
European countries, as for instance exports to Germany increased by 57% to reach 0.01 Mt, with Germany now ranking as its seventh-largest trading partner.

- **Belgium:** Overall exports increased by 16%, from 0.34 Mt in 2021 to 0.39 Mt in 2022. The Netherlands and Türkiye remain the largest export destinations, with exports to the former increasing by 15%, and to the latter by 4%. Exports have increased to both OECD and non-OECD destinations, including a 54% increase to Italy, and a 38% increase to Malaysia.

30. Intra-OECD trade played a key role in 2022. Trade within the EU and within North America (USA, Canada, and Mexico) made up a significant share of global trade flows. Whilst Basel controls have impacted trade to non-OECD countries, bilateral and regional trade agreements among OECD countries could have facilitated this regional trade (Figure 2.7).

**Figure 2.7. Global trade flows in plastic waste and scrap**

Annual reported export volume (tonnes) of HS 3915 (Waste, parings and scrap, of plastics) by destination type in 2022



Note: Flows depict movement from exporters (reporters) to export destinations (reported partner). The width depicts the traded export volume. The aggregate “Europe” contains all OECD member countries located on the continent of Europe, which includes the EU-27, as well as non-EU OECD member countries.

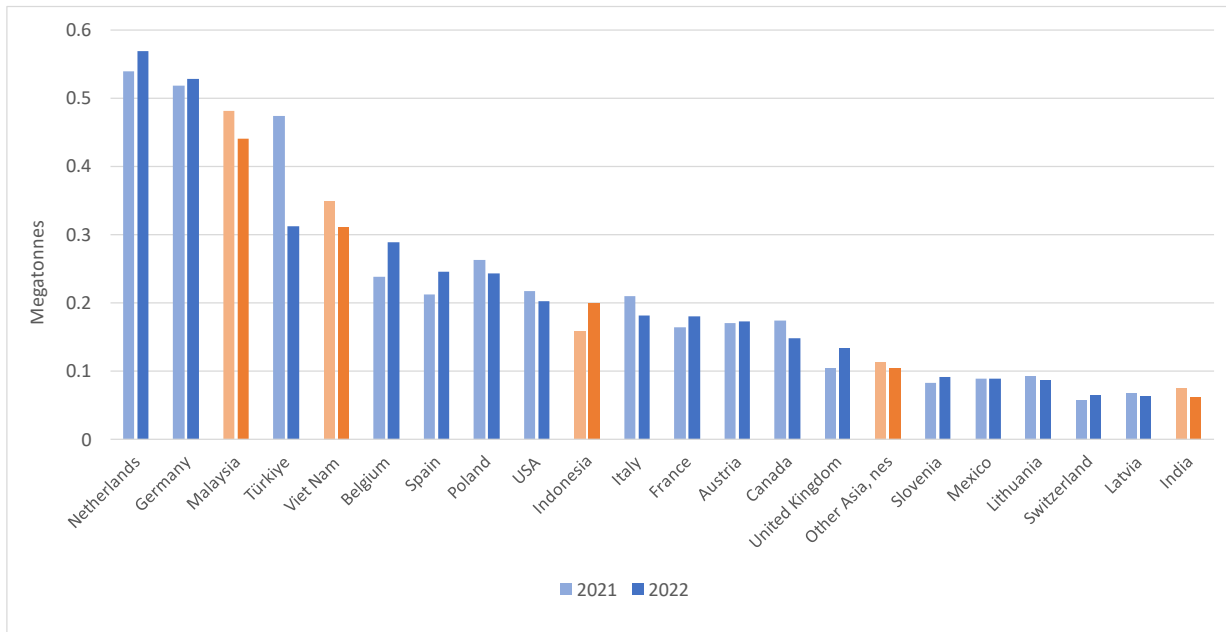
Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

31. Non-OECD countries in Asia remain important export destinations for OECD countries. These include Malaysia, Viet Nam, Indonesia, “Other Asia, nes,” and India. Four of these countries received less waste from OECD countries as compared to 2021, except for Indonesia.

32. Half of the exports to non-OECD Asian countries originate from OECD Pacific (notably Japan). European OECD countries continue to send a substantial share to the region, as do to a lesser extent OECD countries in North America (Figure 2.8).

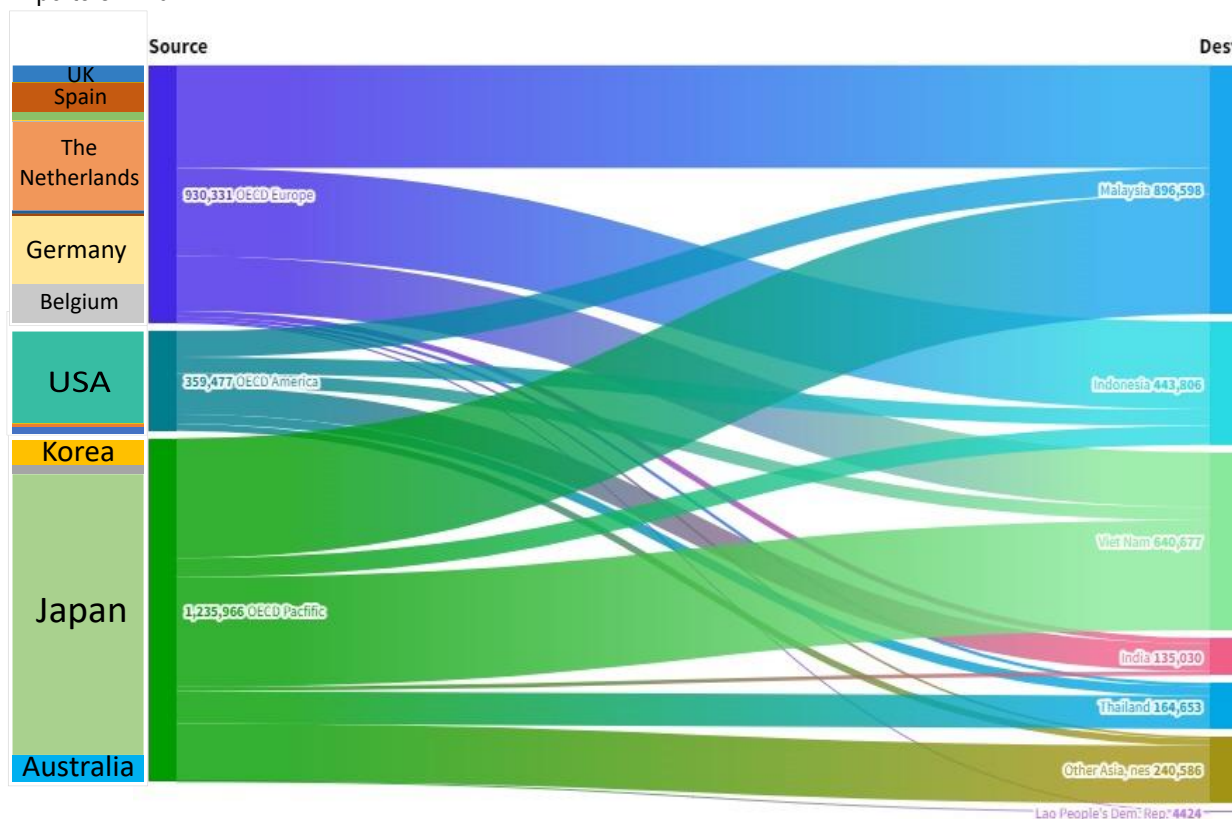
**Figure 2.8. Key destinations of OECD exports of plastic waste and scrap**

Reported OECD annual export volume of HS 3915 (Waste, parings and scrap, of plastics) destined to key importers



Note: Blue = OECD countries; Orange = non-OECD countries; Other Asia, nes (“not elsewhere specified”) includes, *inter alia*, exports to Chinese Taipei.

Reported OECD annual export volume of HS 3915 (Waste, parings and scrap, of plastics) destined to key non-OECD importers in 2022



Note: OECD Pacific includes Japan, Korea, Australia, New Zealand; OECD America includes all OECD countries of North and South America; OECD Europe includes all OECD countries located on the continent of Europe.

Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

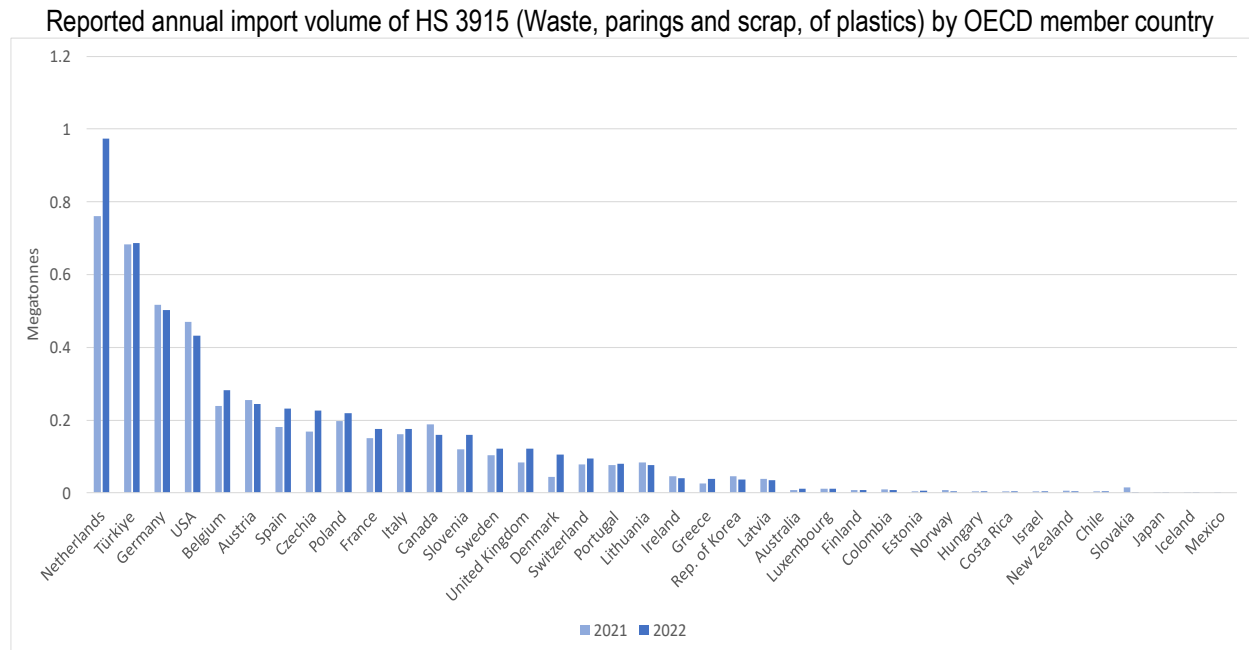
### Imports<sup>7</sup> by OECD countries

33. Imports by OECD countries grew by 10%, from 4.8 Mt in 2021 to 5.3 Mt in 2022. The top five OECD importers were the Netherlands, Türkiye, Germany, USA, and Belgium. 17 OECD countries experienced a decline in imports compared to 2021, while 20 experienced an increase<sup>8</sup>. The greatest decline in imports experienced the USA (a decline of 0.04 Mt, or 8%) reaching 0.43 Mt and Canada (a decline of 0.03 Mt, or 14%) reaching 0.16 Mt. The country for which imports increased most was the Netherlands (an increase of 0.21 Mt, or 28%) to 0.97 Mt (Figure 2.9 and Figure 2.10). However, due to its central location in Europe and a large port, EU imports documented by the Netherlands may also be transshipments.

<sup>7</sup> Note the discrepancy with the ranking of global importers in Figure 2.2 composed of export data. A key limitation of this analysis is that global import and export statistics do not necessarily balance one another. For a detailed discussion of data caveats see Annex A.

<sup>8</sup> Import data for Mexico was unavailable for 2022.

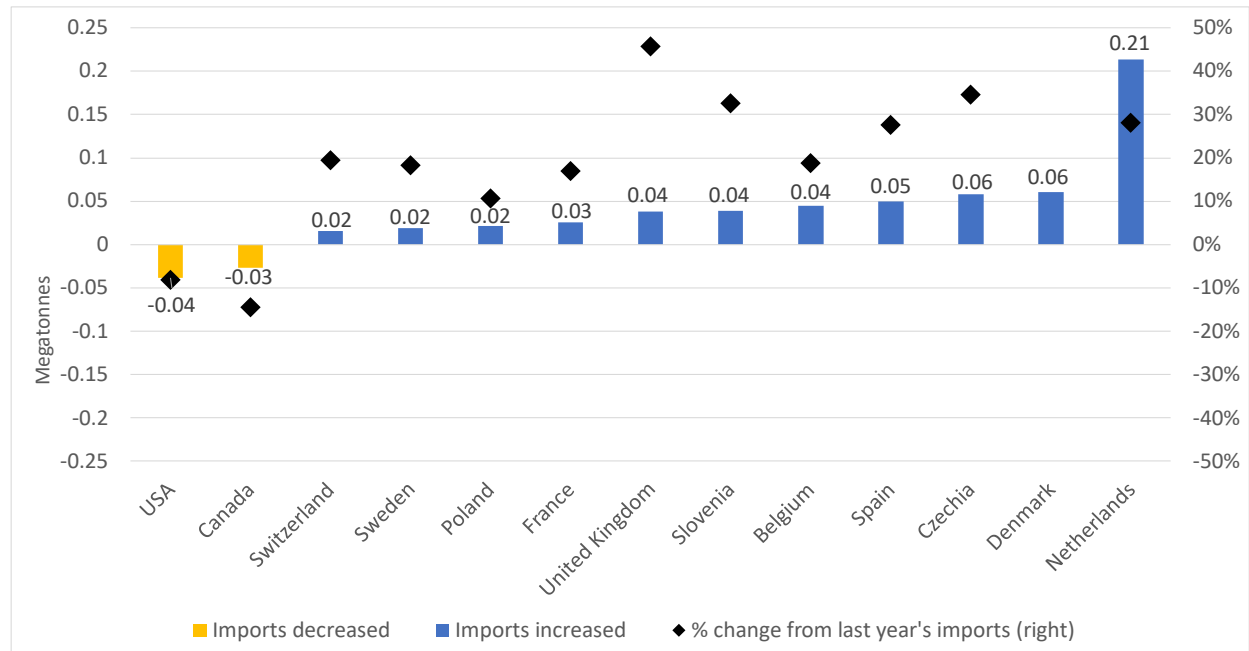
Figure 2.9. 2021 and 2022 imports by OECD member countries



Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

Figure 2.10. Comparison of annual import volumes between 2021 and 2022

Difference in annual import volumes of HS 3915 (Waste, parings and scrap, of plastics) by OECD member country



Note: Includes only OECD countries with an annual absolute difference in imports of 0.02 Mt or above; Denmark, with a % change in imports of 135%, is not included in the graph due to scaling issues.

Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

34. Trade flow developments in 2022 for the largest OECD importers include:

- **The Netherlands:** The Netherlands maintained its position as top importer in 2022 and overall imports increased by 28%, from 0.76 Mt to 0.97 Mt. Its largest import partners are all OECD member countries. EU imports by the Netherlands may also be transshipments. Australia rose to become the tenth-largest trading partner for the Netherlands, recording a 20-fold increase in imports compared to last year, though still small in absolute volume with less than 0.1 Mt.
- **Türkiye:** Imports by Türkiye increased by 1%, from 0.68 Mt in 2021 to 0.69 Mt in 2022. Its largest import partners were Iraq, Germany, the United Kingdom, and the Netherlands. Imports from Iraq and the Netherlands increased by 40% (from 0.07 Mt to 0.10 Mt), and 44% (from 0.05 Mt to 0.07 Mt) respectively, while imports from Germany and the United Kingdom decreased by 11% (from 0.12 Mt to 0.10 Mt) and 32% (from 0.13 Mt to 0.09 Mt) respectively. A notable increase in imports came from Yemen, its seventh-largest trading partner, increasing by 29%, reaching 0.03 Mt.
- **Germany:** Imports by Germany decreased by 3%, from 0.52 Mt in 2021 to 0.50 Mt in 2022. Like the Netherlands, intra-OECD European trade were key. The United Kingdom experienced a 53% increase in imports, reaching a total of 0.03 Mt. Imports from the United States increased two-fold to reach 0.01 Mt.
- **United States:** Imports to the US decreased by 8%, from 0.47 Mt to 0.43 Mt. Most imports originate from its OECD neighbours Canada and Mexico, which together account for over 50% of total imported volume. Other imports are from Germany, Thailand, Honduras, though at smaller volumes. Notably, imports from Thailand increased by more than two-fold in comparison to last year, with total volume of imports amounting to 0.01 Mt.
- **Belgium:** Imports to Belgium increased by 19%, from 0.24 Mt in 2021 to 0.28 Mt in 2022. Owing to its central location in Europe and possession of a large port, imports by Belgium may also be transshipments. Exporters to Belgium are mostly neighbouring countries on the European continent. Imports to Belgium increased from all its top five trading partners, with a notable two-fold increase in imports from the United Kingdom, and a three-fold increase from Bulgaria (its seventh-largest trading partner).

### ***2.2.1. The metric for material quality peaked in mid-2022 and declined afterwards, with intra-OECD traded material maintaining a higher value***

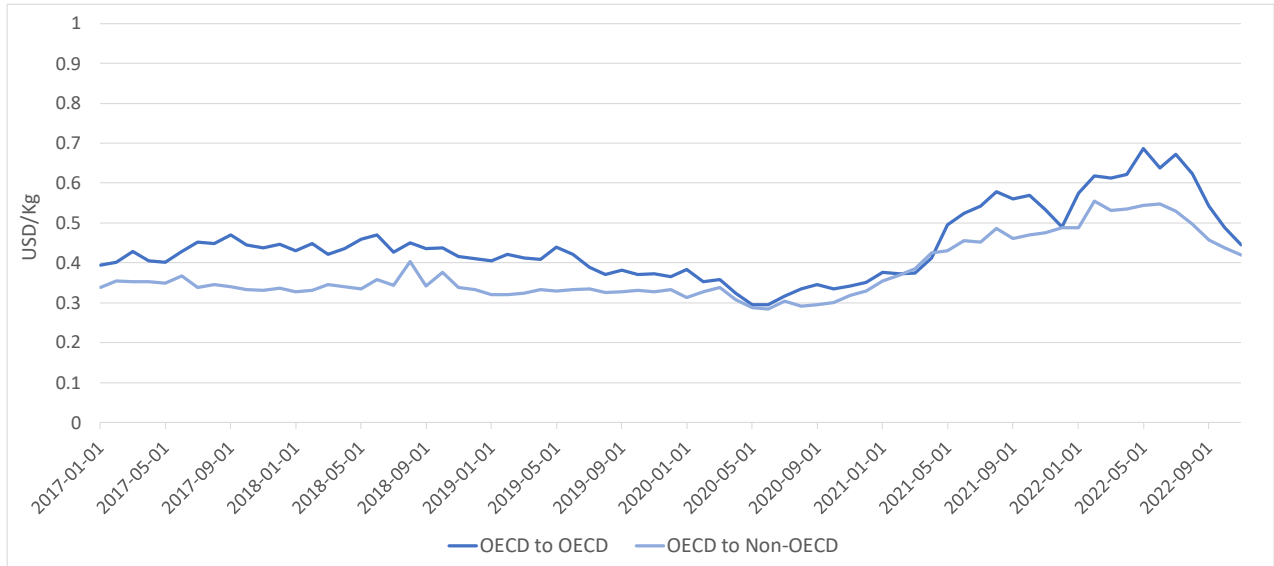
35. Countries report both the volume of trade and the value of the material exported to each of their trade partners. The OECD uses a metric of the reported value per kg to evaluate trends in the quality of traded plastic waste.

36. This value per kg (i.e., trade value) of trade between OECD member countries and from OECD members countries to non-OECD countries slowly converged between 2018 and 2021. The trade value for intra-OECD trade attained a six-year high of 0.69 USD/kg in May 2022, while the trade value for OECD to non-OECD trade also rose to reach its own six-year high of 0.55 USD/kg in February 2022. The increase in trade value over 2021 and through the first half of 2022 may be due to an overall increase in commodity and resin prices that took place over the same period.

37. A divergence occurred between the two values from 2021 to mid-2022, as the value for intra-OECD trade rose faster than the rise in trade to non-OECD countries, suggesting a difference in the quality of waste exported to non-OECD countries. The fall in trade value from May 2022 onwards for both trades coincided with a decrease in commodity and resin prices overall during the same period.

**Figure 2.11. Trade value per volume of exports of plastic waste and scrap by OECD member countries**

Value (USD) per volume (kg) of trade between OECD member countries and exports to non-members (2017-2022 and preliminary data from January to November 2022)



Source : Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

### 2.2.2. The composition of plastic waste traded has not changed between 2021 and 2022

38. Besides the 4-digit code HS3915, UN Comtrade also collects trade data at the 6-digit level, which provides more detailed insights into the composition of plastic waste.

39. HS 391510 (Ethylene polymers) continue to make up the largest single polymer type of plastic waste and scrap exported by OECD countries. Commonly used to make bags and films, this category comprises polymers such as polyethylene (PE), high-density polyethylene (HDPE), and low-density polyethylene (LDPE). The share of ethylene polymers increased from 41% of all OECD exports in 2017 to 46% in 2021. No substantial change has been visible between 2021 and 2022. The absolute volume of ethylene polymers by OECD countries declined, from 2.70 Mt in 2021 to 2.61 Mt, in line with the decline in overall trade volumes.

40. HS 391520 (Styrene polymers) fluctuated between 5% and 6% of total OECD exports since 2019. Comprising polymers such as polystyrene (PS), and expanded polystyrene (EPS), styrene polymers make single-use cutlery, foams, and single-use food containers. Exports of styrene polymers by OECD countries have slightly increased, from 0.30 Mt in 2021 to 0.33 Mt in 2022.

41. HS 391530 (Vinyl chloride polymers) make up the smallest share of OECD exports, approximately 3%. Comprising polymers such as polyvinyl chloride (PVC), vinyl chloride polymers are common inputs to build products, furniture, and a variety of consumer goods, as well as certain types of clothing. In terms of absolute volume, exports of vinyl chloride polymers by OECD countries have slightly declined from 0.20 Mt in 2021 to 0.19 Mt in 2022.

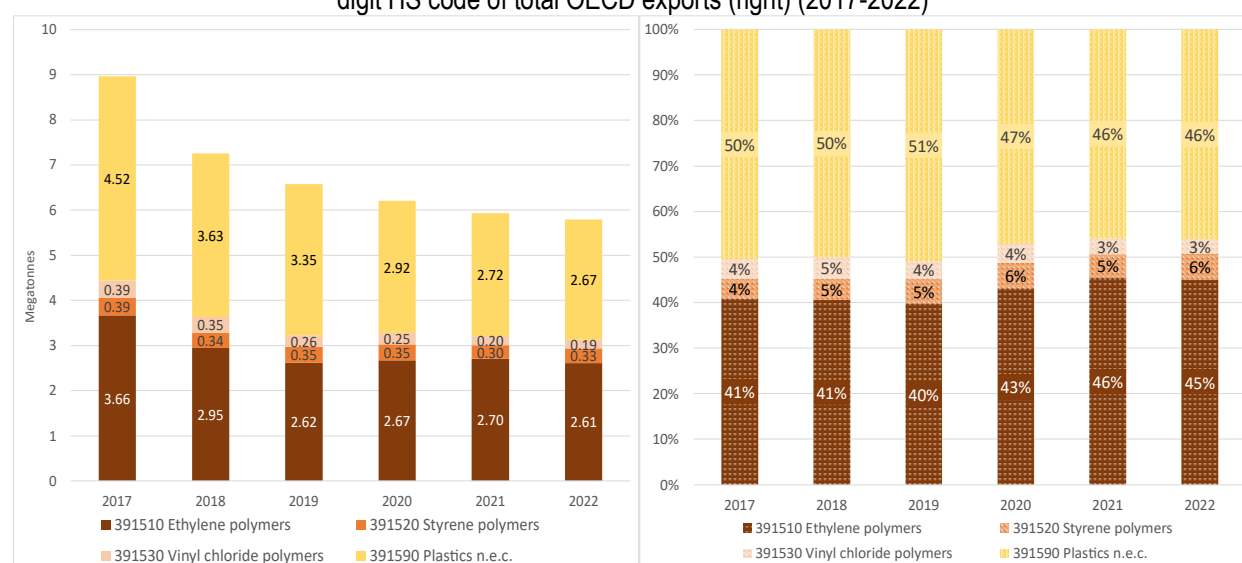
42. HS 391590 (not elsewhere classified) is the largest in absolute volume of exported plastic waste and is the “catch-all” category that includes, among others, polymers commonly marketed as viable feedstock for recycling such as polyethylene terephthalate (PET), which commonly used to make beverage containers and polypropylene (PP), which is used for rigid plastic packaging. However, the category also

includes mixed plastic wastes (Brooks, Wang and Jambeck, 2018<sup>[7]</sup>). Shares of HS 391590 remained constant from 2021 to 2022, but exports in absolute volume declined from 2.72 Mt in 2021 to 2.67 Mt.

43. Waste and scrap from ethylene and polystyrene polymers that is almost free from contamination and destined for recycling is not subject to the new controls on trade. If it is assumed that the majority of plastic waste and scrap traded under “ethylene polymers” (HS 391510) is almost free from contamination<sup>9</sup>, the increased export shares of ethylene polymers that have been observed since 2019 and concurrent lower export shares of mixtures and vinyl chloride polymers, could suggest that more recyclable plastic waste and scrap are being traded (Brown, Laubinger and Börkey, 2023<sup>[2]</sup>) (Figure 2.12).

**Figure 2.12. OECD plastic waste and scrap exports by commodity type**

Annual reported export volume by OECD member countries of 6-digit codes of HS 3915 (left) and shares of each 6-digit HS code of total OECD exports (right) (2017-2022)



Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

44. HS 391530 (vinyl chloride waste, parings and scrap) is exceptional in a sense that it is the only HS code that relates in its entirety to Basel waste entry Y48 and thus entirely subject to stricter controls since the amendments entered into force. Exports of PVC declined continuously from 2017 to 2022, even though there has been no significant decline since the new trade rules came into effect on 1 January 2021.

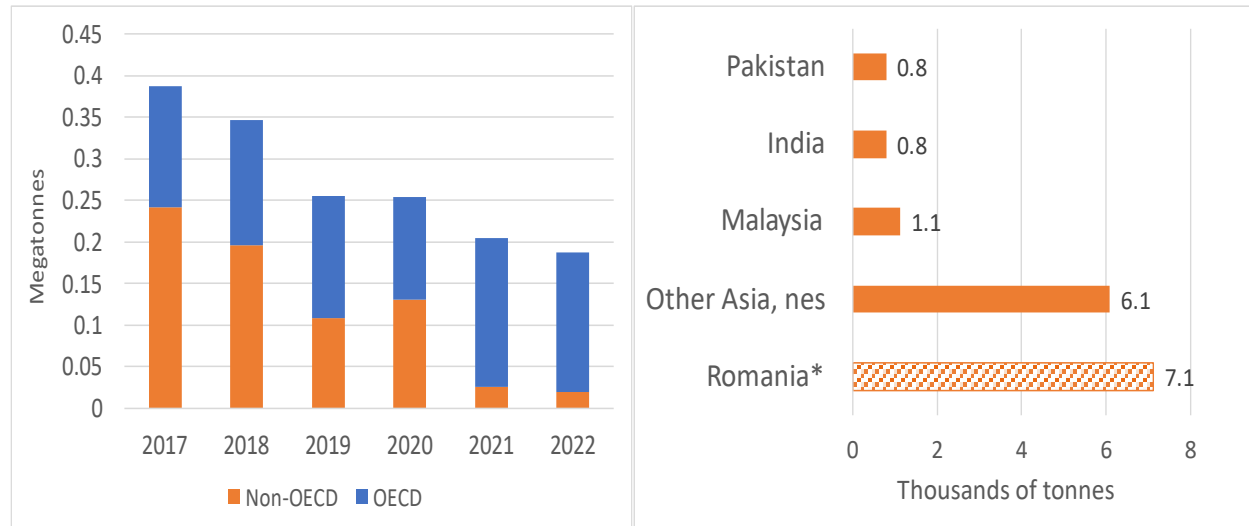
45. In addition, with the plastic waste amendments entering into force, a share of PVC falls under the Basel Ban Amendment, which prohibits exports from OECD, the EU and Liechtenstein to any country other than OECD countries, EU Member States or Liechtenstein. The data shows that exports to non-OECD countries indeed declined since 1 January 2021. Nevertheless, reported trade persists. Approximately 10% of OECD exports of HS 391530 (0.02 Mt) are destined to non-OECD countries, with the largest exporters being the Netherlands, Japan, and the United States (unchanged from last year). The largest importers are Romania<sup>10</sup>, “Other Asia nes,” Malaysia, India, and Pakistan (Figure 2.13).

<sup>9</sup> There is uncertainty about the contamination rate of ethylene polymer plastic waste traded under HS 391510 and to what extent it is in conformity with Basel code B3010 or would fall under Basel code Y48.

<sup>10</sup> Romania is an EU member state and therefore not subject to the Basel Ban Amendment.

**Figure 2.13. OECD exports of vinyl chloride wastes and scrap**

Historical exports of HS 391530 (Vinyl chloride polymers waste, parings and scrap) by destination (left) and 2022 top non-OECD export destinations (right)



Note: Romania, as EU Member State, is not subject to the Basel Ban Amendment. Other Asia, nes (“not elsewhere specified”) includes, *inter alia*, exports to Chinese Taipei.

Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

### 2.2.3. Comparison with data from country reports to the Basel Secretariat

46. The Secretariat of the Basel Convention maintains a database of annual reports by countries that are parties to the Convention, which includes data on waste categories subject to the Prior Informed Consent (PIC) procedure under the Basel Convention. Countries report all plastic waste and scrap trade to UN Comtrade, but Basel Parties need only to report waste subject to the PIC procedure to the Basel Secretariat, which applies to a share of plastic waste from 2021 when Amendments to Annex II, VIII and IX took effect.<sup>11</sup> The authors downloaded each national submission by OECD member countries that are party to the Basel Convention from 2021 and 2022 and compiled a data set.

47. The volume of trade reported in national reports suggests that OECD countries are not yet systematically reporting the plastics waste trade subject to PIC procedure. For 2021, the total amount of reported plastic waste exports by OECD countries subject to PIC procedure was 17 194 tonnes. Illegal traffic is also being reported, with OECD countries having reported 296 tonnes of illegal traffic in plastic waste (Table 2.1). In comparison with the total OECD exports as reported in UN Comtrade, minus the United States<sup>12</sup>, which amounted to 5.2 Mt for 2021, the numbers currently constitute a very small fraction of total trade, suggesting that national reporting of plastic trade flows under Basel is currently not done systematically by all Basel parties. Given that 2021 was the first year where plastic waste formed part of the Basel reporting requirement, the data may improve in future years. It may thus be useful to also review

<sup>11</sup> Since 2021, plastic waste falling under Y48 and A3210 are subject to the Prior Informed Consent (PIC) procedure (Basel Convention, 2023<sup>[22]</sup>) The Basel Convention requires parties to submit annual national reports, which among others should contain information on the export and import of hazardous wastes and other wastes that were subject to control and that took place during the period concerned. The Basel Convention has also been collecting data on transboundary movements of certain other plastic wastes through national reporting prior to 2021, available through the [Basel Reporting Dashboard](#).

<sup>12</sup> The United States is a non-party to the Basel Convention.



aggregate trade flow data submitted through Basel National Reports in future monitoring exercises of this kind.

**Table 2.1. Most reported plastics waste exports by OECD countries subject to PIC were destined for other OECD countries in 2021**

Exporter (Reporting Country)	Importer	Type	Basel Code	Amount (tonnes)
Mexico	United States	Subject to PIC	A3210	116.00
Mexico	United States	Subject to PIC	A4070	4 000.00
Greece	Republic of North Macedonia	Subject to PIC	plastic and rubber	41.38
Greece	Republic of North Macedonia	Subject to PIC	plastic bags and wrapping waste	238.74
New Zealand	Australia	Subject to PIC	Y_***	17.95
Austria*	Hungary	Subject to PIC	Y18	4 554.84
Ireland	United Kingdom	Subject to PIC	Y46	188.02
Ireland	United Kingdom	Subject to PIC	Y46	323.88
Ireland	United Kingdom	Subject to PIC	Y46	375.28
Ireland	United Kingdom	Subject to PIC	Y46	2 343.50
Hungary	Slovakia	Subject to PIC	Y48	130.58
Hungary	Serbia	Subject to PIC	Y48	382.83
Estonia	The Netherlands	Subject to PIC	Y48	493.86
United Kingdom	France	Subject to PIC	Y48	593.50
Slovenia*	Hungary	Subject to PIC	Y48	597.08
United Kingdom	The Netherlands	Subject to PIC	Y48	701.62
Iceland	Sweden	Subject to PIC	Y48	1 764.20
Ireland	Belgium	Subject to PIC	Y9	330.46
Greece	Turkey	illegal traffic	15 01 02**	37.22
Hungary	Italy	illegal traffic	plastic and rubber	22.94
Canada	Malaysia	illegal traffic	Y48	20.20
Canada	China	illegal traffic	Y48	31.60
Australia	Malaysia	illegal traffic	Y48	59.00
Canada	Malaysia	illegal traffic	Y48	125.10
<b>Total (Subject to PIC)</b>				<b>17 193.72</b>
Total (illegal traffic)				296.06
<b>Grand total</b>				<b>17 489.78</b>

Note: \*Reported by Importer; \*\*European Waste Catalogue code for non-hazardous plastic packaging waste, \*\*\*Incomplete submission by Reporter

Source: Authors, calculation based on Basel Convention country level reporting and UN Comtrade (Basel Convention, 2022<sup>[6]</sup>) (UN Comtrade, n.d.<sup>[6]</sup>)

#### 2.2.4. Plastic waste and scrap are under HS codes other than HS 3915

48. National governments and environmental non-governmental organisations have raised concern that the reported trade in HS code 3915 does not include all trade in plastic waste and scrap. Avenues to legally trade under other HS codes include, among others, exports as processed engineered or refuse derived fuel, or as a primary form, e.g. plastic recyclates. This monitoring report reviews trade patterns under the former possibility—trade as fuel—to determine whether there has been an increase in volume after 2020, which would suggest exporters having shifted trading patterns.

49. Plastic waste can be pre-processed through either mechanical or chemical means into an “alternative fuel,” known as Processed Engineered Fuel (PEF) or Refuse-Derived Fuels (RDF)<sup>13</sup>. Doing so enables trade to countries for incineration with energy recovery. Such trade would then not be covered under HS 3915 but under HS 3825<sup>14</sup>, which may contain RDF of municipal waste, or PEF, amongst others.

50. There was a 57% increase of exports of HS 3825 by OECD countries in 2021, from 2.99 Mt in 2020 to 4.70 Mt in 2021. Most of this trade was to other OECD countries, from non-EU European countries to countries within the EU. The United Kingdom and Switzerland, two OECD countries, were largely responsible for most the rise in exports of HS 3825 for year 2021. Sweden received most of the UK’s waste, while Germany received most of Switzerland’s.

51. As this increase happened the same year as implementation of the new Basel trade rules for plastic waste, it is possible that some of this increase is linked to more stringent requirements for trade in plastic waste. Most of the rise in non-OECD imports of HS 3825 for 2021 was accounted for by increased imports in Cyprus<sup>15</sup>, an EU country. In 2022, total OECD exports of HS 3825 declined slightly to 3.95 Mt, but this is still much larger compared to 2020 levels (Figure 2.14).

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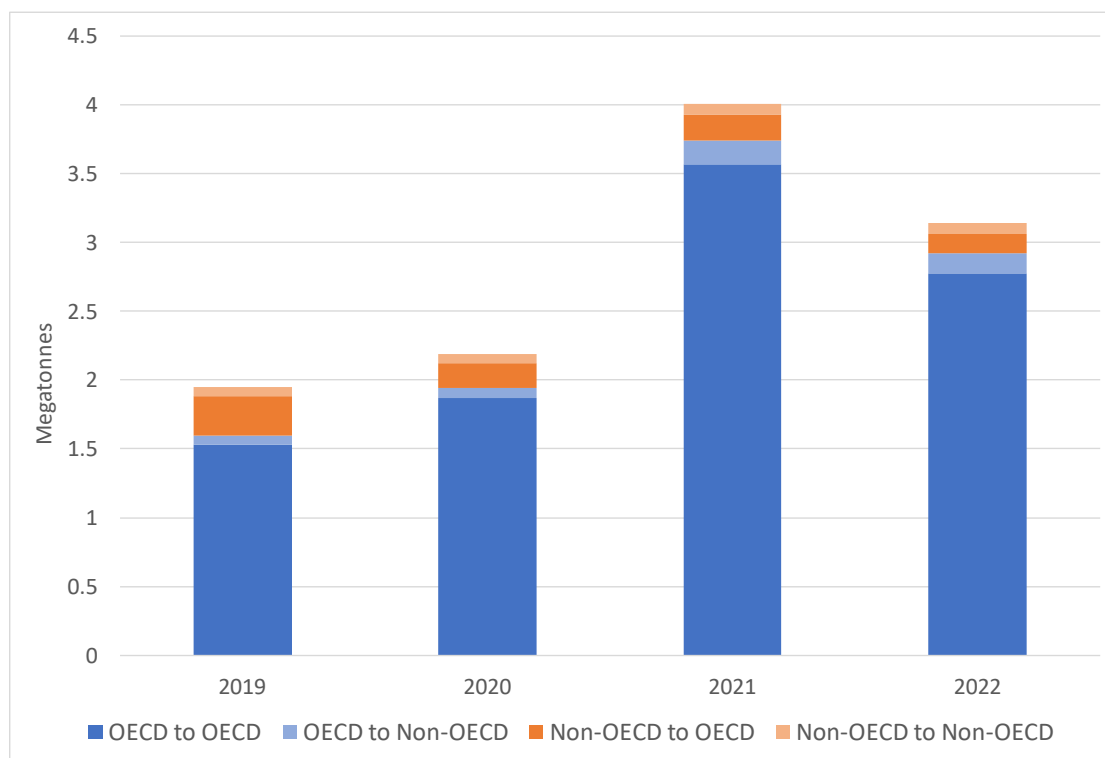
<sup>13</sup> A type of waste-derived fuel, RDF is manufactured from municipal solid waste (MSW) made up of a mix of end-of-life materials (consisting of non-hazardous, residential, industrial, commercial, construction and demolition waste) that contain among others plastic, wood, and metal, and is used as input to the waste-to-energy process.

<sup>14</sup> HS 3825 comprises miscellaneous chemical products, which include diverse sub-categories such as municipal waste, sewage sludge, clinical waste, and wastes of metal pickling liquors (i.e., substances used to remove impurities on metal surfaces, usually containing acids), hydraulic fluids, brake fluids and anti-freeze fluids.

<sup>15</sup> Note by the Republic of Türkiye. The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the “Cyprus issue”. Note by all the European Union Member States of the OECD and the European Union. The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

**Figure 2.14. OECD and non-OECD trade flow developments for HS 3825**

Historical exports of HS 3825 by OECD countries (blue) against historical exports of HS 3825 by non-OECD countries (orange)



Source: Authors, based on UN Comtrade data (UN Comtrade, n.d.<sup>[6]</sup>)

52. A further analysis of 6-digit codes of HS 3825 revealed that most exports (81%) of HS 3825 were under the code 382510, or municipal solid waste. As municipal solid waste likely comprises plastics to a large part, the sharp rise in HS 3825 exports in 2021 may indeed suggest that exporters have shifted to trading waste containing plastic under this and possibly other HS codes. Even though the largest recipients of this trade are other OECD countries with developed waste recovery systems, the case of HS 3825 demonstrates that plastic waste is capable of being traded under other HS codes and there is a risk that some plastic waste trade is bypassing the 2021 controls.

53. Exporters may also potentially categorise plastic waste and scrap not as “waste”, but as a primary form ‘recycled’ product (e.g. after having gone through some form of processing), thus this volume would also not be reported under HS 3915. In practice, though these types of plastic recyclates (e.g. shredded plastic to be used to make new products) are visually distinguishable from virgin plastics—typically having a grey colour compared to the white colour of the latter—there is currently no data available that tracks trade in secondary plastics, either for recycled primary plastics or for other recycled plastic products (UNCTAD, 2020<sup>[9]</sup>), adding to currently existing difficulties in tracking down possible alternative pathways for trade in plastic waste.

54. Further monitoring exercises could delve deeper into these developments.

### Box 2.1. Relevant work published or underway

The following works involving trade in plastic waste and scrap are noteworthy:

- *OECD's forthcoming Regional Plastics Outlook (RPO)*: This regional spin-off of the *Global Plastics Outlook* seeks to shed light on the drivers of plastics use and impacts of plastic waste for the ASEAN +3 countries. It also aims to present policy scenarios adapted to the regional context. The OECD has tentatively scheduled for its release in mid-2024.
- *OECD's forthcoming "Policy Scenario Analysis to Eliminate Plastic Leakage to the Environment by 2040"*: This report features an analysis of modelled policy scenarios that countries can take, to achieve the target of ending plastic pollution by 2040. It aims to support the work of the Intergovernmental Negotiating Committee (INC) to develop an international legally binding instrument on plastic pollution. A [Summary for Policymakers](#) was released prior to INC-3 and the full report foreseen to be published in the second half of 2024.
- *OECD's Environmental Performance Review (EPR) of the United States, 2023*: The EPR of the United States contains a full chapter dedicated to the topic of marine (plastic) litter, including a multi-country comparison of policy approaches to combat marine litter for the United States, Japan, and Indonesia. It also includes a discussion on the role of policies regulating plastic waste trade to address marine litter (OECD, 2023<sup>[10]</sup>).
- *SYSTEMIQ's Towards Ending Plastic Pollution by 2040 (published September 2023)*: This report presents a set of 15 global policy interventions to end plastic pollution by 2040 and also features a discussion on the plastic waste trade. The Nordic Council of Ministers commissioned this work (SYSTEMIQ, 2023<sup>[11]</sup>).
- *International Pollutants Elimination Network (IPEN) report on the "Hidden Numbers" of the Plastic Waste Trade (published March 2023)*: This report broadens the analysis on UN Comtrade data to include other HS codes that may capture trade in plastic waste, making the case that a mere analysis of HS 3915 likely underestimates the volumes of plastic waste traded globally (IPEN, 2023<sup>[12]</sup>).
- *Paper on the plastic waste trade in Türkiye*: this recent paper examines the impact of China's National Sword policy on plastic waste flows into Türkiye (Dhingra, 2023<sup>[13]</sup>).
- *INTERPOL reports on the sharp rise in plastic waste crime since 2018, and the nexus between organised crime and pollution crime*. Leveraging data collected across national law-enforcement agencies, INTERPOL published two reports examining the rise in transboundary waste crime and illegal waste shipments since 2018, and the links between organised crime groups and environmental crime (INTERPOL, 2020<sup>[14]</sup>) (INTERPOL, 2022<sup>[15]</sup>).
- *An examination of European plastics trade five years after the introduction of the Chinese plastic import ban* (Joltreau, 2022<sup>[16]</sup>).
- *UNCTAD Plastics Trade Database*: A database maintained by UNCTAD tracking trade across the lifecycle of plastics (UNCTAD, 2020<sup>[9]</sup>) (UNCTAD.Stat, 2022<sup>[17]</sup>).
- *Basel Action Network's (BAN) Plastic Waste Trade Data*: BAN provides ongoing analysis, figures and metrics on plastic waste trade derived from UN Comtrade and country level data (Basel Action Network, n.d.<sup>[18]</sup>).

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## Annex A. Methodology

55. UN Comtrade is a database that aggregates the import and export statistics reported by UN Member States' statistical authorities. The database has information reported on the trade in waste parings and scrap of plastic (annual and monthly data). The following Harmonised Code (HS)<sup>16</sup> and its four subcategories were considered for this analysis:

- HS 3915: Waste, parings and scrap, of plastics
  - HS 391510: Ethylene polymers waste, parings and scrap;
  - HS 391520: Styrene polymers waste, parings and scrap;
  - HS 391530: Vinyl chloride polymers waste, parings and scrap; and
  - HS 391590: plastics not elsewhere classified (n.e.c.), a catch-all for other material.<sup>17</sup>
- HS 3825: Residual products of the chemical or allied industries, not elsewhere specified or included; municipal waste; sewage sludge; other residual products

56. Each reported entry includes data fields on the specified HS code, trade flow (import/export/re-import/re-export), trading partner, volume (kg), and value (USD).

57. The authors extracted UN Comtrade data on 13 October 2023 and conducted the following analyses:

- Data visuals of volume data:
  - Time-series:
    - export destinations (globally and by OECD member states, yearly and monthly data),
    - Imports and exports of OECD member states, and
    - Subcategories (6-digit HS codes);
  - Sankey diagrams of major exporter and importer flows.

58. Qualitative monitoring complements the analysis of trade patterns with updates on the trade policy context and a description of relevant literature by other organisations.

59. As well, authors used 2021 export and import data from national reports to the Basel Convention to complement the analysis. At the date of analysis, the 2021 national reports were the most recent ones available on the Basel Convention website.

60. Key limitations of this methodology lie in the limits of the available data. These include:

- UN Comtrade does not provide information on the ultimate destination or process used for the management of the waste (i.e. recycle, landfill, or incineration) (Brooks, Wang and Jambeck, 2018<sup>[7]</sup>). The exercise will thus only show trade flows that cannot be linked to the ultimate fate of the traded product or potential environmental impacts. It also does not allow to distinguish transit countries from final importers.

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<sup>16</sup> The World Customs Organization develops and updates The Harmonised System (HS).

<sup>17</sup> The HS assigns specific six-digit codes for varying classifications and commodities. Countries can add longer codes to the first six digits for further classification. For instance, the United States uses a 10-digit code to classify products for export, known as a Schedule B number. HS 391590 contains the 10-digit code 3915.90.0010 for polyethylene terephthalate (PET) plastics (US Trade, 2020<sup>[20]</sup>).

- UN Comtrade HS codes are not aligned with waste codes of Annexes of the Basel Convention or Appendices of the OECD Decision and therefore does not allow the authors to draw conclusions about trade flows of individual waste code categories.
- Data reported in national reports to the Basel Convention is aligned with waste codes, but appears to be incomplete for 2021, the latest year reported.
- Reported data can include mistakes, omissions, and/or infrequent reporting. For example:
  - Global imports and exports statistics do not necessarily balance one another;
  - The sum of monthly data may not equal the figure reported in annual submissions;
  - The sum of the four different six-digit HS codes may not equal the figure reported for the overall four-digit HS code.

61. To mitigate data issues, the authors have taken the follow actions:

- Use export volume data for global figures<sup>18</sup>;
- Exclude abnormal data entries: i.e., volume data that is orders of magnitude larger than the reporters' median entry<sup>19</sup>;
- Place preference on HS code four-digit annual data submissions; and
- Exclude UN Comtrade data for 2023 from the analysis, which was still considered to be too incomplete.

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<sup>18</sup> Export data was assumed to be more complete than import data. Therefore, this report uses predominantly export data, also for figures showing key importers globally, but uses both export and import data to assess and depict by OECD countries.

<sup>19</sup> Methodology for omitting outliers is adapted from (Berthou and Emlinger, 2011<sup>[21]</sup>).