A perspective report on material flow modelling of plastics in Norway

PLAST ICENE

The role of humans in the life of plastic

PROJECT REPORT

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PROJECT NO. : 302005784
VERSION : 1
DATE : 2025-01-15

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Suggested Citation: Shraddha Mehta, Pavel Stránský, Emily Christine Cowan, Silje Woxholth Sørfonn, Siri Karine Hanslien-Olsson, Jens Henning Breivik. (2025). *A perspective report on material flow modelling of plastics in Norway.* PLASTICENE.

CLIENT(S) : The Research Council of Norway
PROJECT NO. : 302005784
CLASSIFICATION : Open

ABSTRACT
This report presents a state of the art on plastic accounting in Norway and highlights the existing data gaps to map the flows and stocks of plastic polymers in the Norwegian economy. The findings from the existing studies on modelling the material flows of plastics in Norway are summarised and compared to identify the limitations of the different studies. Lastly, recommendations on improving the existing data and knowledge gaps are discussed.

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01 THE PLASTICENE PROJECT

PLASTICENE is a project funded by the Norwegian Research Council. It consists of four partners – SINTEF (represented by SINTEF Ocean, SINTEF Industry, SINTEF Community and SINTEF Helgeland), Deloitte, WWF Norway, and House of Knowledge – and is coordinated by SINTEF Ocean. The project takes a full life-cycle approach to building new knowledge and addressing important processes for increased plastic circularity and effective plastic waste management, with the aim of supporting improved plastic material utilization and protecting the environment from plastic pollution.

This is critical, as more than 460 million tons of plastic are produced globally every year as of 2019[1]. Plastic waste and emissions of plastic to nature represent significant societal challenges, and increased knowledge of the plastic resource flow is essential. A key part of this knowledge includes the plastic accounting in Norway, allowing governments, companies, and other organisations access to knowledge on the flows and stocks of plastic polymers throughout Norway.

Understanding where and how much plastic polymers are circulating throughout an economy is a critical importance, especially considering the need for emerging technologies stemming from the potential UN legally binding instrument on plastic pollution.

The aim of this report is to highlight the existing models for calculating inflow and outflow of plastics through the Norwegian economy and the key gaps needing to be addressed for more accurate and transparent estimations of the current use of plastics and future projections of expected waste.

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[1] OECD, 2023 "Global plastic waste set to almost triple by 2060" https://www.oecd.org/environment/global-plastic-waste-set-to-almost-triple-by-2060.htm

02 INTRODUCTION

This work has been carried out as part of the PLASTICENE project to develop new knowledge and research capacity towards addressing sustainable plastic use in Norway

Material Flow Analysis (MFA) is a crucial tool to map the volumes of the different plastic polymers in the production, use and end-of-life stage. MFA models of plastics are important in developing strategies for reducing plastic waste and improving recycling processes.[2] Furthermore, material flow modelling exercises also help in identifying existing data gaps and highlighting the need for more comprehensive data and policies to address the environmental challenges posed by plastic polymers.

There have been a variety of publications on plastic inventories and material flow analysis in the last years, with a variety of scopes, methodologies and geographical boundaries. Modelling the material flow of plastics for a particular economy or country is data intensive, and there are often two different approaches used in data collection i.e. top-down and bottom-up approach. A top-down approach mainly uses statistical data from import, export and domestic production and then divides the volumes into polymer type and sector while the bottom-up approach looks into the sectors and product groups to estimate amount and type of plastic and then extrapolating the data to national or regional level. The former method is suitable to ensure not to exclude products that have been overlooked or errors in estimation or extrapolation. This is also the method that is used in the most comprehensive MFA studies on plastic flows in Europe.[3,4]

Increasing the reuse of the more than 91% of global plastic waste being improperly disposed of, is vital to have in place before the end of global negotiations on the UN treaty to end plastic pollution. For the reuse of plastic, in addition to the total amount available for reuse, knowledge of the polymer composition of products and additives is extremely important. Plastic additives can have both positive and negative effects on recycling[6]. Some additives can preserve the integrity of the plastic thus making it more suitable for recycling whereas various pigments can often pose as a barrier in recycling.

Downstream actors in the value chain of plastic need a better overview of the volumes as well as the quality of plastic waste that will be available in the future in order to efficiently handle, reuse and recycle the large volumes. Reliable estimates on plastic waste that will be generated in future are needed for identifying the potential for new players in the market. For circular business models that aim to reuse or re-purpose plastic products, an insight in the volumes of the products in use and in stock are essential to efficiently plan logistics and operations around where the biggest stocks of plastic are.

Knowledge base for understanding the plastic flows in Norway

Recent publications on plastics in the Norwegian economy have built inventories with higher levels of detail and more systematic data collection and estimation.[5,6,7,8] These studies have also identified some significant data gaps, and there is a certain degree of uncertainty in the results presented. These estimates can be improved by the use of additional information that is either not available or reported today or is not open access due to its competitive nature.

Objectives of this study are:

1. Collation of existing data and results to represent the flows of plastics in the Norwegian economy
2. Developing an interactive tool for data visualization
3. Identify data gaps and give recommendations for future data needs

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[2] https://link.springer.com/article/10.1007/s10163-024-02110-6
[3] https://www.sciencedirect.com/science/article/pii/S0921344921003426
[4] https://publications.jrc.ec.europa.eu/repository/handle/JRC130613
[5] Abbasi et al., https://www.sciencedirect.com/science/article/pii/S0160412022006201
[6] https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2633368
[7] Marhoon et al, 2024, https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3129389
[8] Gisle et al., https://www.ssb.no/natur-og-miljo/miljoregnskap/artikler/plastic-account-for-norway/_/attachment/inline/2b28faca-7256-4a69-9ec2-5f1931cc5116:27c1b19f43463bc59590b6151c465db85fa48b96/NOT2023-35.pdf

03 METHODOLOGY

2.1 Review of data and MFA Models

A review of the national, EU and international datasets on products containing plastic, plastic waste, and plastics in use has been done. Available secondary data and statistics on trade and manufacturing of all product groups containing plastic or plastic packaging have been reviewed. The existing models and studies on mapping of plastics in Norway have also been reviewed and the findings are compared. The data collated from two sources has been integrated in a visualization tool. The major data gaps in building robust MFA models of plastics in Norway are also identified.

2.2 Visualization

The data visualization platform was built on aggregated information from Abbasi et al.[5] and Mahroon et al.[7], aimed at illustrating how polymers flow through various sectors and accumulate in different products within an economy. By offering an interface accessible to researchers, scientists and policymakers, it reveals the underlying stocks and flows that govern plastic usage. The platform is designed for scalability, ensuring that new studies can be integrated over time without compromising clarity or consistency. It can be accessed at:
https://app.powerbi.com/view?r=eyJrIjoiYmFiM2ZhNTctYWQ1Ny00OGM3LWI2ZjQtMjM5ZDg5OTc0ZjI5IiwidCI6ImUxZjAwZjM5LTYwNDEtNDViMC1iMzA5LWUwMjEwZDhiMzJhZiIsImMiOjh9

The visualization is divided into several pages that guide users through increasing levels of detail. An introductory page presents the platform's overall purpose and partnership structure, while a simplified Sankey diagram shows polymer flows at a broad scale. A more detailed Sankey offers granular insights into transformations, end-of-life pathways, and inter-sector movements, complemented by a stock page that identifies how plastics accumulate in various sectors. There is also a flow diagram comparison tool for aligning results across studies and a regulations page that summarizes current legislative frameworks.

Finally, the tool's public accessibility allows diverse users to gain immediate insight into the complexities of plastics management. The tool can allow stakeholders to investigate volumes of plastic and polymers by different sectors in Norway and give an overview of the regulations governing plastic use. The information base can in turn lead to exploring supply chain efficiencies and regulatory nuances.

04 Results

There are several studies and plastic accounts published for Norway in recent years with different system boundaries[9], scope and a different approach, i.e. either a top-down approach or a bottom approach. For instance, some studies have considered total plastics and not individual polymers while others have mapped several polymers individually. Quantification of microplastics is also one aspect that is either included or excluded in the studies reviewed. Table 2-1 gives a detailed overview of the studies that are reviewed.

The main findings from the studies reviewed are:

- Total plastic put on market in Norway per year is between 620-1300 Kt
- LDPE has the largest inflow out of all the polymers followed by PP while EPS and PVC have the highest volumes in stock.
- The total stock of plastic or plastic in use is between 3100-4800 Kt of which the largest stock is in the buildings and construction sector.
- The largest yearly flow of short-lived plastic is of packaging products accounting for about 40% of the total input of plastic put on market per year.
- Annual plastic waste in Norway is around 460-620 Kt out of which 50% is incinerated whereas about 19-25% is sent for material recovery.
- There is about 15 Kt (i.e. about 2% of plastic waste) lost to the environment and plastic from wear and tear of automobile tyres being the largest source of microplastics while consumer packaging (LDPE, PP) being the largest source of macro-plastics.

TABLE 2-1: Overview of the previous studies that have been published on plastic accounting in Norway

Title and reference	Year modelled	Total plastic input in kt	Per capita consumption in kg/capita	Total plastic output (waste) in kt	In use or stocks	System description
Mapping Plastic and Plastic Additive Cycles in Coastal Countries: A Norwegian Case Study, Marhoon et al[7].	2020	760 ± 200	140 ± 36	590 ± 110	4470 ± 330	The model covers 13 different plastic polymers (LDPE, HDPE, PP, PS, PET, EPS, PVC, PUR, PA, PC, ABS, cellulose acetate (CA), and rubber) that make up ~87% of the European plastic demand, 49 products distributed into 10 plastic application sectors: packaging, building and construction (B&C), agriculture, automotive, electrical and electronic equipment (EEE), boats and fisheries (B&F), clothing, household textiles, technical textiles, and others.
A high-resolution dynamic probabilistic material flow analysis of seven plastic polymers; A case study of Norway, Abbasi et al.[5]	2020	620 ± 23	114	460 ± 22	3400 ± 56	Seven polymers are included in the study: LDPE, HDPE, PP, PS, EPS, PVC, and PET. The model consists of six processes at the production and manufacturing stage, nine industrial sectors with 40 individual product categories, 13 processes of the waste collection system, six processes of the recycling system, and eight final sinks.
Achieving Circularity Synthesis Report A LOW-EMISSIONS CIRCULAR PLASTIC ECONOMY IN NORWAY, Systemiq[10]	2021	710	NA	502	NA	The stocks and flows of plastics in Norway are quantified and seven use sectors are analysed. Annual plastic waste generated from these sectors are quantified.
Materialstrømmen til plast i Norge – hva vet vi?, Mepex[11]	2020	NA		540	3100	Total plastic in use and yearly plastic waste generated and divided by 10 product categories.
Plastic account for Norway, Gisle et al.[8]	2021	1310		620	NA	Total amount of primary, semi-finished and finished plastic in products put on the market and plastic waste generated.

[9] System boundary is defined as a boundary in time (such as a reference year) and space (geographical area, country etc.)

05 Discussion

These existing models give a detailed overview of the biggest flows, stocks and sinks of plastic in the Norwegian economic sectors and identifies the major product categories containing plastic. Considering that both a top-down and a bottom-up approach are used, the results of total plastic put on market do not fall within the same order of magnitude. However, the main findings in terms of largest economic sectors using plastic, largest stocks and sources of waste are consistent throughout the literature. The estimated value for the total waste generated annually shows good agreement between all the different studies. Some data gaps mainly on product composition and amount of packaging remain consistent across all studies.

A few limitations emerge while comparing the studies and these are important to consider in building more robust models for plastic accounting in Norway in the future. Some of the studies are based on a model framework covering the major economic sectors in EU and they do not give a detailed representation of some major Norwegian economic sectors mainly aquaculture and fisheries. Other limitations is that the data used for inflow of plastics to Norway are highly aggregated trade statistics and some studies have made use of simplistic lifetimes leading to a possible underestimation of long-lived plastic stocks. Some studies also omit or simplify the progressive leaching of microplastics during product use, thus underestimating these chronic release pathways10. Finally, the precise distribution of leakage to marine versus terrestrial compartments is sometimes treated with coarse assumptions, reducing policy relevance for coastal areas where release pathways are critical.

Norway's plastic per capita consumption surpasses the EU average due to unique socio-economic and industrial characteristics, as well as waste management practices. First, Norway's higher disposable income supports increased purchasing power and demand for goods heavily packaged in plastics, such as consumer goods and food products. The country's reliance on plastic packaging for convenience and food preservation is particularly notable, as it addresses geographical challenges like dispersed populations and long transportation distances, ensuring product longevity and reducing food waste7.

Moreover, a significant proportion of plastic in Norway originates from industrial sectors, especially construction, which requires large quantities of durable plastics such as PVC and polyethylene for insulation and piping5. This industrial reliance contributes to Norway's high per capita plastic usage.

Norway has implemented effective Extended Producer Responsibility and deposit-return schemes for recycling, the actual reuse of recycled plastic remains limited due to insufficient industrial demand for recyclate. An overview of the existing as well as upcoming Norwegian, EU and Global regulations for the major economic sectors in Norway are presented in the Table 5-1 in the Appendix. The regulations for production stage, use as well as end of life stage are presented.

Approximately 19-25% of plastic waste is recycled, and 50% is incinerated for energy recovery, reflecting a gap in circular practices. Despite government efforts to align with EU recycling targets, the incineration of non-recyclable plastics and significant reliance on virgin plastics persists. Inaccurate data on material composition of products, packaging and additives pose a challenge to efficiently implement circularity in the plastic value chains and increased transparency and accounting is key in sustainably managing plastic in the Norwegian and global economy.

Data gaps and recommendations for better data availability

Along with regulating how plastics are produced, used and treated, there is an urgent need in increasing transparency in the plastic value chain from producers to recycler and more stringent regulations on reporting of accurate polymer composition, product packaging and additives must be introduced. Plastic packaging and the amount of packaging that is imported along with imported goods must be registered or reported. Better information flow on the quality and the composition of products from the use phase to the recycling and regenerative phase should be enabled. Standard categories of plastic waste across the sector should be implemented (different private companies use different types of categories for e.g. hard plastics, soft plastic, films).

The knowledge base on plastic flows in Norway has definitely improved in the recent years and there are several studies with varying degree of detail and research approach that are published. However, there are still some limitations in the data and information available today and improving access to data is crucial to improve the current estimates on plastics in Norway. Better estimates on plastic in use and expected waste volumes in the future will enable a data-driven decision process in a sustainable management of the plastic value chain.

Acknowledgements

This work is funded by the Plasticene project financed by the Research Council of Norway, #318730. We acknowledge inputs from our colleagues Tuva Grytli and Lara Veylit.

[10] https://www.systemiq.earth/reports/achieving-circularity/synthesis/

[11] https://handelensmiljofond.ams3.digitaloceanspaces.com/reports/Materialstr%C3%B8mmen-til-plast-i-Norge-Hva-vet-vi_-1.pdf

06 Appendix

Table 4-1: Overview of the existing and upcoming regulations for the major economic sectors in Norway

Sectors	Norwegian Regulations	European Regulations (EU)	Global Regulations	Sources or links
Aquaculture and fisheries	1. The Norwegian Pollution Control Act (E) 2. The Norwegian Aquaculture Act 3. Proposed regulation on producer responsibility for fisheries, aquaculture and receational fishing (P, U) 4. Marine resources Act no. 37 (E)	DIRECTIVE (EU) 2019/904 of 5 June 2019 on the reduction of the impact of certain plastic products on the environment	1. Potential provisions in the future Global Plastics Treaty (E) 2. UNCLOS – United Nations Convention on the Law of the Sea (U, E) 3. International Maritime Organization € 4. The FAO Code of Conduct for responsible fisheries	https://www.miljodirektoratet.no/globalassets/alle-tema/kjemikalier/veiledning/ny---produkter/forslag-til-forskrift-om-produsentansvar-for-fiskeutstyr-med-plast.pdf/download; 255327-l-0525_akvakulturloveneng PDF (www.regjeringen.no) https://eur-lex.europa.eu/eli/dir/2019/904/oj
Agriculture	Voluntary plastic return scheme through Grønt Punkt Norge (E)	1. EU plastics Strategy (P, U, E) 2. EU Waste Framework Directive (E)		https://www.grontpunkt.no/innsamling/landbruksplast?gad_source=1&gclid=Cj0KCQjw-5y1BhC-ARIsAAM_oKke9_uB0HDNTOfdv6SVcGmVwxkVhVkwWvlH0e78lYwTv3BzUth4iGkaAqPfEALw_wcB
Buildings & transport infrastructure	1. Norwegian National Transport Plan 2. Forskrift om gjenvinning og behandling av avfall (avfallsforskriften) kap. 14 Betong og tegl fra riveprosjekter (E)			https://lovdata.no/dokument/SF/forskrift/2004-06-01-930
Automotives	Forskrift om gjenvinning og behandling av avfall (avfallsforskriften) kap. 4. Kasserte kjøretøy og kap. 5. Innsamling og gjenvinning av kasserte dekk (E)	1. Directive 2000/53/EC on End-of-Life Vehicles (ELV Directive New updates to ELV Directive will ensure recyclability of Plastics in Automotives and tyres) [E]		https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en#:%7E:text=Directive%202000%2F53%2FEU%20on,set%20out%20in%20Annex%20II.
EEA (Electronics and electrical appliances)	Forskrift om gjenvinning og behandling av avfall (avfallsforskriften) kap. 1 Kasserte elektriske og elektroniske produkter (E)	Extended producer responsibility (WEEE directive) (E)		https://produsentansvar.miljodirektoratet.no/
Private consumption	County specific plastic waste segregation + deposit system for PET € EPR for certain SUP products underway	1. EU Single Use Plastics Directive (P) 2. EU Directive on Packaging and Packaging waste, and Directive on Plastic bags (P,E)		https://www.miljodirektoratet.no/hoeringer/2024/juni-2024/horing-av-forslag-til-forskriftsregulering-av-utvidet-produsentansvar-for-enkelte-engangsprodukter-av-plast/
Manufacturing	Waste Control Act §32 (E)			https://www.regjeringen.no/en/dokumenter/pollution-control-act/id171893/#:%7E:text=Purpose%20of%20the%20Act,to%20promote%20better%20waste%20management.
Hospitality and services	Forskrift om gjenvinning og behandling av avfall (avfallsforskriften) kap. 10a Utsortering og matieralgjenvinning av enkelte avfallstyper (E)			https://environment.ec.europa.eu/topics/plastics/single-use-plastics_en
Other (Overarching)	1. EU Waste framework directive 3. Norwegian Pollution Control Act 1. Norwegian Packaging Ordinance	1. EU Green Deal (P,U,E) 2.Plastics Strategy (P,U,E) 3. EU Urban waste water directive (E)	3. UN Global plastics Treaty (P,U,E)	https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en%20;%20https:/environment.ec.europa.eu/strategy/plastics-strategy_en
Key: (P) Production Regulations (U) Use Regulations (E) End of Life Regulations				

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