European Commission

Study to support the Commission in gathering structured information and defining of reporting obligations on waste oils and other hazardous waste

Final Report

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Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

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"Study to support the Commission in gathering structured information and defining of reporting obligations on waste oils and other hazardous waste"

Contract No 07.0201/2018/789021/ENV.B.3

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Contract

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Client:

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Abbreviations / Glossary

a	Year (e.g. t/a)
BTX	Benzol (benzene), toluol (toluene) and xylol (xylenes)
BuOH	Butanol
CAGR	Compound annual growth rate
CEIP	Centre on Emission Inventories and Projections; responsible for coordinating the emission related work of EMEP; www.ceip.at
CHP	Combined heat and power generation
CLRTAP	Convention on Long-range Transboundary Air Pollution
Concawe	Environmental science for European refining
CPA	Classification of Products by Activity; European statistical product classification by six-digit code
DCM	Dichloromethane (methylene chloride)
DEE	Diethyl ether
DMAc	Dimethylacetamide
DMF	Dimethylformamide
EC	European Commission
ECHA	The European Chemicals Agency
ECSA	European Chlorinated Solvents Association
EDC	Ethylene dichloride
EEA	European Economic Area
EMEP	European Monitoring and Evaluation Programme; Cooperative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe, provides scientific support to the CLRTAP on, among others, the emission inventories
EoL	End-of-life (=waste; = spent)
EoW	End-of-waste
ELV	End-of-life vehicle
EPR	Extended Producer Responsibility
ESIG	European Solvents Industry Group
ESRG	European Solvent Recycler Group
ESVOC	European Solvents Downstream Users Coordination
ETBE	Ethyl tertiary-butyl ether

EtOH	Ethanol
EWC	European Waste Catalogue
EWC-STAT	European Waste Classification for Statistics (EWC-STAT); Commission Regulation (EU) No 849/2010 of 27 September 2010 amending Regulation (EC) No 2150/2002 of the European Parliament and of the Council on waste statistics
FF	Furfural
FuelsEurope	European petroleum refining industry
GEIR	Groupement Européen de l'Industrie de la Régénération
HC	hydrocarbon(s)
HWE	Hazardous Waste Europe
HSPA	Hydrocarbon Solvents Producers Association
IPA	iso-propyl alcohol, iso-propanol
IED	Industrial Emissions Directive: DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 November 2010 on industrial emissions (integrated pollution prevention and control) - 2010L0075 — EN — 06.01.2011
IPA	Iso-propanol, isopropyl alcohol
JRC	Joint Research Centre
kt	Kilo tonne(s)
LCA	Life Cycle Assessment
LoW	European List of Waste. COMMISSION DECISION of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste; 01.06.2015
MEK	Methyl ethyl ketone, butanone
MeOH	Methanol
MFSU	Manufacture, fabrication, supply and use
MIBK	methyl iso-butyl ketone
MS	EU Member State(s)
MTBE	Methyl tertiary-butyl ether
NMP	N-methyl pyrrolidone
NMVOC	Non-methane volatile organic compounds
OSPA	Oxygenate Solvent Producers Association
OVAM	Public Waste Agency of Flanders

PER	Perchloroethylene
PoM	Placed on the market
PRO	Producer Responsibility Organisation
PrOH	Propanol
PRODCOM	Statistics on the production of manufactured goods; http://ec.europa.eu/eurostat/web/prodcom/data/database
RDF	refuse-derived fuel
REACH	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC
RMOA	Analysis of the most appropriate regulatory management option, Regulatory Management Option Analysis
RoHS	Directive 2011/65/EC, Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment
rta	release-to-air; the rta-ratio gives the percentage of solvent released to the atmosphere as VOC compared to the solvent input into an application
STS BREF	Best Available Techniques (BAT) Reference Document on Surface Treatment Using Organic Solvents including Preservation of Wood and Wood Products with Chemicals (JRC 2019, final draft)
T, t	tonnes
TAME	Tertiary amyl methyl ether
TAEE	Tertiary amyl ethyl ether
TEA	Triethylamine
THF	tetrahydrofuran
ToR	Terms of Reference for this study
TRI	Trichloroethylene
UNECE	United Nations Economic Commission for Europe; UNECE negotiated 5 environmental treaties, including Convention on Long-range Transboundary Air Pollution (CLRTAP)
VOC	Volatile Organic Compounds

WFD	Waste Framework Directive (WFD); Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste; 05.07.2018
WShipR	Waste Shipment Regulation, Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste https://ec.europa.eu/eurostat/web/waste/transboundary-waste-shipments
WStatR	Waste Statistics Regulation, Regulation (EC) No 2150/2002 on EU waste statistics; 18.10.2010
WSR	Waste Statistics Regulation
WT BREF	Best Available Techniques (BAT) Reference Document for Waste Treatment (JRC 2018)

Abbreviations for Member States

AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

Executive summary

Part 1 Waste oil

A new formal reporting obligation on waste oils has been established by Article 37 of the Waste Framework Directive. At present, there is no structured and harmonised data on waste oils available at EU level. The official format for reporting on waste oils was adopted in June of 2019 (Commission Implementing Decision (EU) 2019/1004, Annex VIII). The first collected data for the reference year 2020 will, however, only be available by mid-2022.

As important preparatory work for waste oils reporting, the European Commission commissioned this study. In this regard, the Oeko-Institut supported DG Environment in developing the draft data format including a format for the quality check report and a guidance document to support users of the new data format.

Better knowledge in the field of lubricant oils and waste oils is needed in the forefront of formal reporting on waste oils by Member States. Therefore, this study analyses the situation of oils and waste oils in the EU-28 and describes the resulting base oil, lubricant oil and waste oil mass flows. The results of this study are based to a large extent on data and information from a stakeholder consultation process (including EU associations and a Member State survey) and extensive desktop research.

The material flows were analysed according to the stages of the oil life cycle, beginning in this study with the production of base oils. It considers the production and consumption of lubricant oils, followed by the generation of waste oil and ending with the treatment of waste oil. During all life cycle stages imports and exports need to be considered.

Base oils

Base oils are the starting material for the production of lubricant oils. Base oils can generally be categorised into mineral, synthetic and bio base oils. A further distinction can be made between virgin and re-refined base oil. Most base oils result from the crude oil refinery process, while re-refined base oils result from the regeneration of waste oils in re-refineries.

A further classification of base oils into five Groups (I to V) was introduced by the American Petroleum Institute (API) and is often referred to. This categorisation is based on the following main criteria: percentage of saturates, sulphur content and viscosity index. These criteria determine the properties of the API base oil groups I to V.

Lubricant oils

Lubricant oils are produced by blending base oils of different characteristics and adding additives to the blend. The lubricant oils typically consist of about 75% to 80% base oil. However, this depends on their application. The properties of the lubricant oil, e.g. viscosity, high resistance to oxidation or low pour point, will depend on the characteristics of the base oils and the additives.

Applications

There are many different applications of lubricant oils in diverse areas, whereby it is generally differentiated between automotive and industrial applications. The use of the specific lubricant oils and their share of the total lubricant oils placed on the market differ between countries and depend, among other things, on the structure of the country's industry.

Engine oils represent up to about half of all lubricant oils placed on the market. Hydraulic oils with about 15% to 20% of the total represent the second largest market share. The category 'Other industrial oils not used for lubrication' includes for example stamping oils, gas washing oils or heat transfer oils. Metalworking oils, for example for drilling or rolling, are oil / water emulsions with a water content of around 90%.

Finally, there are also lubricant oils such as greases and process oils that do not result in any waste oil. A main portion of these oils are process oils used in the manufacturing of products for the chemical-technical industry. Since they find their way into products, they can no longer be recovered as waste oils.

Where possible, marine oils are considered separately, as their mass flows are not traceable due to their use in international shipping traffic.

Losses and collection

Whether oil placed on the market becomes waste oil after use depends on the specific application of the oil. Engine oil used in vehicles for example is partly burned during driving. The same applies to process oils which are also lost for collection when they are converted into products.

This implies that a certain amount of oil will get lost and only the remaining share will be available for collection as waste oil. In this sense, we refer to 'unavoidable losses' and 'collectable waste oils'. **The share of oil placed on the market which is collectable is identical to the 'return rate'**. Country-specific return rates mainly depend on the specifics of the vehicle fleet, the structure of the industry and imports / exports of lubricant oils within product types (in particular vehicles).

In practice, additional losses referred to as 'avoidable losses' will occur. Therefore, the amount of collected waste oil is often less than the collectable waste oil. Such avoidable losses can result from potentially illegal activities or improper management of waste oils. Possible examples are engine oil changes and subsequent inadequate disposal of the oil by private individuals or the burning of waste oil in small waste oil burners for heating purposes. Waste oil losses present a risk of oil-contamination of soil and water and the loss of valuable base oil that could potentially be re-refined.

Treatment of waste oils

Different processes can be applied for the treatment of waste oils. The main options for treatment are re-refining to base oils, preparation of fuels, energy recovery (e.g. in cement kilns, lime works, power plants) and hazardous waste incineration.

The waste management hierarchy prioritises the regeneration (re-refining) of waste oil over its use as fuel and other energy recovery. Engine, gear, hydraulic, machining, insulating, heat transmission and lubricant oils are generally suitable for re-refining while, e.g. halogenated waste oils, PCB containing waste oils, waste oils originated from or mixed with biodegradable oils or emulsions from metalworking are not.

The main output of the re-refining process of waste oil is about 60% to 75% of base oil. The remaining output consists of light ends, gas oil, asphalt flux and about 3% to 8% water.

Waste oil mass flows

The results of the analyses of the situation of oils and waste oils in the EU-28 are presented in the waste oil material flow diagram in Figure 12-2 of the main text of this study.

Base oils and lubricant oils

Overall in the EU-28, less than 8 million tonnes of **virgin base oils** were produced according to estimates based on the years 2013 to 2018. About 0.68 million tonnes of

re-refined base oil resulting from regeneration of waste oil in the EU-28 were additionally produced in 2017. Re-refined waste oil accounted for only about 8% of total base oil production in 2017. However, a possible trend is emerging indicating that re-refined base oil as a "sustainable" or "green" product could become a sales argument. Today's production capacities of about 8.2 million tonnes of virgin base oil in the EU-28 are still dominated by API group I base oil (about 62%). However, a clear shift to group II (and higher base oil groups) can be observed in the EU-28. France, Germany, Italy, Netherlands and Spain represent the main share of the production capacities with each of them contributing more than 1 million tonnes.

The EU-28 is a **net exporter of base oil**. The mass flows in Figure 12-2 suggest that net exports of base oil and use for additives together account for about 4 million tonnes of base oil in 2017. The largest part of these 4 million tonnes of base oil can be allocated to net exports. The remaining part of the overall base oil production was used for the production of about 6 million tonnes of lubricant oils in the EU-28. These lubricant oils include additives, which to a large extent originate from the aforementioned 4 million tonnes of base oil. The EU-28 was also a **net exporter of lubricant oils** of about 1.5 million tonnes in 2017. Italy is the main net exporter (extra-EU trade) of lubricants (about 0.8 million tonnes in 2018).

In total, about 4.3 million tonnes of **lubricant oils** were placed on the market in the EU-28 in 2017. About 0.35 million tonnes of marine oils were not taken into account, as their use, due to worldwide maritime transport, is not traceable. Germany, the UK, France, Spain and Italy are the main consumers in the EU-28, together consuming about 71% of the total lubricant oil.

During the use phase lubricant oils are imported and exported together with new and used vehicles but also other products. Imports and exports influence the amount of lubricants placed on the market in Member States. In countries with small vehicle fleets but large vehicle production sites, export flows of engine oil can account for a relevant share of total consumption of engine oil. In Slovakia for example this results, due to export of new vehicles, in a net export of about one fifth of the total engine oil placed on the market.

Most of the **losses** which occur during the use phase of lubricants are **unavoidable**. This includes mainly process oils and greases or engine oil burned during driving. Unavoidable losses could only be determined for vehicle engine oils and account for only for this application, about 0.7 million tonnes (about 43% of the engine oils placed on the market). In total, about 2.0 million tonnes of waste oils are **collectable** in the EU-28. This corresponds to an overall return rate of about 47% (share of collectable waste oils of the total consumption of lubricants). In mathematical calculations, this results in unavoidable losses of about 2.3 million tonnes.

Other **losses** can occur due to improper management of waste oils and are considered **avoidable**. On the level of the EU-28 differentiation between avoidable and unavoidable losses is only partially possible (see engine oil above) and the total losses account for about 2.7 million tonnes of waste oils. These losses are calculated from the difference of the amount collected, about 1.6 million tonnes, and the amount placed on the market, 4.3 million tonnes. Again, calculated purely mathematically, the difference with the unavoidable losses (about 2.3 million tonnes) results in a quantity of about 0.4 million tonnes of avoidable losses. However, this estimate is associated with a high degree of uncertainty. Burning waste oil in small-scale heaters for heating purposes and engine oil changes in passenger cars carried out by private car holders are regarded as possible activities for such avoidable losses.

Overall, about 38% of the lubricant oils placed on the market (4.3 million tonnes) in the EU-28 was collected as waste oil (1.6 million tonnes). This corresponds to a **collection rate of collectable waste oil of about 82%** (share of the actual collected waste oil of the collectable waste oil).

Imports of waste oils into the EU-28 are rather small, estimated at about 20 000 to 30 000 tonnes per year. In total, about 1.6 million tonnes of **waste oils** were **treated** in the EU-28 in 2017. The main share, about 61%, was input into **re-refineries** and resulted in about 0.68 million tonnes of re-refined base oil. About 24% of total waste oil and thus the second highest share was treated to produce fuels and about 11%, the third highest share, was used for energy recovery in cement, lime, steel and power plants.

Conclusions

The study revealed that increasing the collection of waste oil should be the main focus for improvement. Establishing quantitative collection targets is identified as a key factor for increased collection. Collection targets together with extended producer responsibility (EPR) schemes present best practice examples on national level for supporting the collection of high amounts of waste oil.

However, the existence of quantitative collection targets and EPR schemes does not guarantee high collection rates, but rather depends on the concrete implementation. A collection target needs to be significantly high. An EPR system requires concrete standards such as the collection of waste oil free of charge, a comprehensive area-wide collection system and communication and information for consumers on waste oil generation, collection free of charge and environmental impacts if released into the environment or burned in inappropriate heaters.

As long as not all collectable waste oil is actually collected a risk of oil-contamination of soil and water remains. Mandatory and **ambitious targets for waste oil collection** on the EU level and mandatory **EPR schemes with defined requirements** could help to increase the collection of waste oil and minimise the risk of pollution.

With regard to circular economy and resource efficiency, strict implementation of the waste management hierarchy is the key factor. The waste hierarchy prioritises the re-refining of waste oil over energy recovery.

In order to implement a clear priority for re-refining, **quantitative targets for waste oil regeneration** have been identified as a determining factor. Enforcement of restrictions for the export of waste oil to incineration and co-incineration when there is no re-refinery in the country supports the achievement of higher regeneration shares. Therefore, the development of a mandatory quantitative target for re-refining waste oil on the EU level should be explored.

Furthermore, the study indicates that Member States that have developed specific end-of-waste criteria for waste oils defining fuel products derived from waste oil tend to favour processing to fuel rather than countries without it. This may indicate that such end-of-waste criteria defining fuel products are a negative driver in promoting regeneration of waste oil to base oils.

Overall, the development of two mandatory quantitative targets on the EU level are above all considered the main measure for improvement: a significant collection target for an increased amount of collected waste oil and a significant regeneration target for achieving higher amounts of re-refined base oil.

Part 2 Spent solvents and other hazardous organic liquids

The second part of the study presents the information gained with respect to the current situation of (spent) solvents and other hazardous organics liquids in the EU Member States.

Objective and scope

Together with waste oils, spent solvents and other hazardous liquid chemical wastes constitute a relevant share of total European hazardous waste generation. While no specific targets have been set in the WFD with respect to the generation, collection or treatment of solvents and other hazardous liquid chemical wastes in the European Union, it is clear that these hazardous wastes need to be handled in an environmentally safe manner and in compliance with the waste hierarchy. In order to promote compliance with these two paramount requirements a quantitative analysis of the relevant flows is first needed for spent solvents and other hazardous liquid chemical wastes. Moreover, a better understanding of the possibilities to recycle these streams is required.

Approach

In order to provide a structured overall picture of the situation in the EU Member States a material flow analysis for spent solvents was conducted. It included all stages along the life cycle from primary production via the use phase to their end-of-life as well as a quantitative analysis of the treatment options currently applied to spent solvents. An analysis of the contribution of a set of other hazardous organic waste streams, in particular organic still bottoms and reaction residues, was included in the analysis of the waste stage. Moreover, the situation of solvent recycling practices was analysed. Based on the gathered information elements which may contribute to enhance solvent recycling were identified.

Data and information were gathered by analysis of Eurostat statistics and stakeholder consultations. The latter included the contact with associations, in particular those representing the solvent-producing and recycling industries, as well as a survey conducted among the relevant Member State authorities. Desktop research was used to complete information.

Results

An overview over the solvent quantities produced, used and finally treated as waste in the European Union is included in Figure 23-1 in the main text of this study. The overall **production of solvents** in the EU-28 is reported at approx. **5 million tonnes**per year for oxygenated and hydrocarbon solvents (JRC 2019). Based on expert judgments from the industry it was estimated that the reported solvent volume is composed of oxygenated and hydrocarbon solvents in approximately equal shares. The estimated breakdown by representative substances is included in Figure 20-6 in the main text. **Chlorinated solvents** are estimated to be produced in volumes of around **0.2 million tonnes**per year or lower. Volumes of nitrogen-containing solvents placed on the European market are publicly available only as ECHA tonnage bands from which a volume in the range of several tens of thousands of tonnesper year at least was estimated. Seven countries are mainly responsible for the production of organic solvents in Europe (BE, DE, FR, UK, NL, ES, IT).

The analysis of the data on **trade** did not allow for a comprehensive statement for the solvent-relevant substances included in this study. The main reason was that several compounds are rather included in large aggregates in statistics. Moreover, as for production, information on the share going to solvent use is necessary. Hence estimates were only derived for some exemplary substances.

With respect to **solvent use** the repartition by application is reported to have remained essentially constant over the last ten years with over 50% of hydrocarbon and oxygenated solvents going to the coatings sector (mainly paints & coating, as well as printing and adhesives) (ESIG 2019). Based on NMVOC[1] emission inventories it is estimated that **2 to 2.6 million tonnesof solvents are released into the air** per year (ESIG and EEA/EMEP inventories, respectively). The major contribution to these losses comes from the coatings sector, followed by domestic solvent use, the use of chemical products in industrial manufacturing and processing[2], printing and degreasing. From a circularity point of view emissions into the air as CO_2 also represent losses to the material cycle for cases where the solvents are captured in off-gas and oxidised for NMVOC abatement.

For the **waste stage** of solvents, public waste statistics offer data on spent solvents for all MS but the included waste streams are limited to a defined aggregate (WStatR Category 01.1).[3]

A total **generation of spent solvents** (WStatR Cat. 01.1) of **2.4 million tonnes**per year is reported by Eurostat. This value includes impurities, but an average solvent content cannot be reliably indicated. In terms of quantities a strong concentration of the waste generation in a few Member States can be observed. With approx. 700kt/a, by far the highest volumes are reported for DE (1/3 of EU-28 generation). The seven major producing Member States (BE, DE, FR, IT, NL, ES, UK) plus Ireland[4] report >100kt/a each and together account for more than 90% of the EU-28 generation of spent solvents. 15 Member States[5] report a generation of around and below (some even far below) 10kt/a and together account for only ≈2% of European generation. AT, DK, FI, HU and SE lie in between and account for the remainder.

A total **treatment of spent solvents** of **1.8 million[6] tonnes**per year in the EU-28 is reported by Eurostat with an average recycling share of approx. 40%. The corresponding volume of **750kt/a of spent solvents going to recycling** seems to be comparably high. Based on industry sources (ESRG 2019) a spent solvent input volume of approx. 500kt/a is estimated. Particularly high recycling shares are reported for IT and ES (>80%) where it is reportedly more difficult to access incineration options (ESRG 2019). For DE, FR and BE approx. 33% are reported to be recycled. The 20 MS with low spent solvent generation report an average recycling share of only 20%.[7]

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[1] Non-methane volatile organic compounds; NMVOC emissions are of environmental concern due to their contribution to ground-level ozone and have to monitored and reported under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP), see www.ceip.at, last access: 19/12/14.

[2] According to the EEA/EMEP inventories; NFR Category 2.D.3.g Chemical products (EEA 2016/2019)

[3] With respect to recycling the numbers generally refer to external recycling activities even if some internal recycling may also be included. Internal (on-site) recycling is practised in many industries. It simultaneously decreases net solvent consumption and waste generation but was not quantified in the present study.

[4] Due to important pharmaceutical industry, see e.g. CTC (2010).

[5] BG, HR, CY, **CZ**, EE, EL, LV, LT, LU, MT, **PL**, **PT**, RO, SK, SI (CZ, PL, PT around 10kt/a)

[6] The quantities on waste generation and treatment reported by Eurostat can differ for several reasons (see Eurostat WStatR metadata): while waste generation reports the volume generated in the defined territory, for treatment import and export activities have to be considered. Moreover, the data on generation include secondary wastes. For waste treatment only the final treatment shall be reported. Finally, from generation to final treatment some weight may be lost by drying/evaporation.

[7] This value may still be lower as it is based on a substantial contribution from DK where according to MS survey (2019) no solvent recycling takes place.

A discrepancy was found for the volumes reportedly going to energy recovery: While Eurostat indicates approx. 500kt/a (incineration with energy recovery and co-processing), according to the cement industry association approx. 700kt/a of spent solvents are used as alternative fuel in cement kilns (CEMBUREAU 2019).

For **spent solvents trade** the sum of all exports reported by the MS roughly equals the sum of all imports: 180kt and 165kt, respectively, suggesting that extra-EU trade is limited.[8] The identified traded volumes lie at approx. 10% of the spent solvent volume treated inside Europe. At Member State level trade activity may be significant.

The volume of **regenerated solvents produced** is estimated to be **close to 400kt/a**. Among the member companies of the solvent recyclers association[9] approx. 50% of the regenerates are recovered as mixed solvents while the rest are single substances. Chlorinated solvents are regenerated in volumes of around 10kt/a.

As indicated above, not all solvent-containing waste streams are included in the respective Eurostat waste statistics category (WStatR Cat. 01.1). While particularly waste paint[10] was found to occur in similar volumes as Cat. 01.1 spent solvents, no further quantification could be carried out due to a lack of generalisable average solvent contents. The volumes of other solvent-containing waste streams (spent brake fluids, antifreeze and degreasing agents) are overall comparably small[11].

Other hazardous organic liquids (still bottoms and reaction residues) may also constitute a relevant share but are reportedly less attractive to solvent recyclers as a general rule. From the perspective of solvent recyclers these streams generally contribute less recoverable material so that rather the utilization of their calorific value or the recovery of valuable metals are elements for consideration (ESRG 2019).

Conclusions

A major reason for the varying shares of spent solvents going to recycling in the Member States seems to be different approaches to the **implementation of the waste hierarchy**. An evaluation of the different approaches in the MS is required to identify levers for improvement.

Source segregation of spent solvents should be promoted as one prerequisite to facilitate recycling, especially for high purity recycling. Beside the need for a commitment from solvent users to source segregation, other contributions to recycling from the users' side include choosing solvents with recyclability in mind[12] and generally accepting regenerated solvents as a suitable alternative to the primary product.

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[8] This is reasonable given that under the Basel convention trade with hazardous wastes is restricted to OECD countries (WShipR).

[9] Membership of solvent recycling companies in ESRG estimated at 80% by ESRG (2019).

[10] LoW 080111* "waste paint and varnish containing organic solvents or other hazardous substances" originating from MFSU and removal of paint and varnish. No further specification is made so that this LoW code may contain waste paints of any composition (solvent-based, water-based, high solids) provided they have a certain organic solvent or other hazardous content.

[11] Except for degreasing waste in CZ where MS survey (2019) identified a contribution of nearly 20% of the CZ generation of all hazardous waste streams included in this study (see Chapter 22.1, Annex VIII).

[12] This refers to the fact that already when deciding on the solvent to be used in the process, preferably in an early stage of development, the end-of-life options should be taken into consideration. As an example, if high recycling rates can be achieved with a more costly solvent (from economic or ecological point of view) it may be more beneficial from a life cycle perspective than a cheaper solvent which cannot be recovered.

In order to increase the available feedstock for recycling, the **feasibility of channeling solvents in off-gases to material recovery** should be analysed. A systematic evaluation should include the technical options[13] for all relevant applications and should elaborate on the economic impacts and environmental benefits from a life cycle perspective. If feasibility is generally proven, the waste hierarchy as specified in Article 4 WFD might prospectively be applied to captured solvent-laden off-gases, too, implying the general prioritisation of solvent material recovery over oxidation. Increasing the awareness among solvent users that the solvents contained in their off-gases are potentially too valuable to be oxidised could be a starting point.

[13] e.g. with respect to energy requirement and quality of regenerates

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Part 1 WASTE OIL

Final Report

1 Context of waste oils

Regulation on waste oil has a long lasting history in the European Union. More than 40 years ago the Directive 75/439/EC on waste oils entered into force to establish harmonised management of waste oil across the EU. In 1987 some major amendments were established with the result that among the different options for recovery, priority is given to the regeneration of waste oil over its incineration.

The Waste Oil Directive 75/439/EEC and the Hazardous Waste Directive 91/689/EEC were repealed as of 12 December 2010. The aspects of the two directives are integrated into the Waste Framework Directive 2008/98/EC, especially Articles 17 to 21 and 35. With regard to waste oil, Article 21 stipulates that Member States (MS) shall take the necessary measures to ensure that

(a) waste oils are collected separately, where this is technically feasible;

(b) waste oils are treated in accordance with Articles 4 (waste hierarchy) and 13 (protection of the environment and human health);

(c) where this is technically feasible and economically viable, waste oils of different characteristics are not mixed and waste oils are not mixed with other kinds of waste or substances, if such mixing impedes their treatment.

The questionnaire for Member States to report on the implementation of Directive 2008/98/EC was established in 2012[14] and covers the following aspects:

(1) Please describe the scheme applied in the Member State for separate collection and treatment of waste oils.

(2) Has the Member State taken measures to prevent mixing of waste oils with different properties or waste oils with other wastes or materials? What kind of measures?

(3) What additional measures, such as technical requirements, producer responsibility, economic instruments or voluntary agreements does the Member State apply for the purpose of separate collection of waste oils and their proper treatment?

(4) Please further indicate whether waste oils are subject to requirements of regeneration in the Member State and whether the Member State restricts the transboundary shipment of waste oils from its territories to incineration or co-incineration facilities in order to give priority to the regeneration of waste oils.

The most recent implementation report available to us refers to the period 2013 – 2015[15] and covers the issue of waste oil and the four aspects above.

[14] (2012) 2384 final: Commission Implementing Decision establishing a questionnaire for Member States reports on the implementation of Directive 2008/98/EC of the European Parliament and of the Council on waste; Brussels, 8.4.2012

[15] Final Implementation Report for Directive 2008/98/EC on Waste: 2013 – 2015, Service request under the framework contract No ENV.C.2/FRA/2013/0023, Report for DG Environment, European Commission, prepared by Eunomia and partners, 8 June 2018. (EC-WFD 2018)

In the context of the Circular Economy Package, the amending Directive 2018/851 recently introduced certain changes to the Waste Framework Directive (WFD). Relevant for this study is in particular that Member States shall report data on oil placed on the market and the amount of waste oil collected and treated. Therefore, a data format for the reporting on waste oil in compliance with Article 37 WFD had to be developed.

Considering the timeline for the implementation of the above-mentioned format, the first data set from this data collection will be available by mid-2022 at the earliest. To get a better overview on (waste) oil mass flows in the EU in the meantime, the contractor gathered quantitative data on lubricant oils placed on the market, waste oils collected and treated and other (waste) oil flows.

2 Waste oil reporting format

At present, there is no structured and harmonized data on waste oils available on EU level. This issue of missing information in the field of waste oil mass flows has been addressed by means of a new formal reporting obligation on waste oils. Based on the amended Article 37 WFD, *"[...]4. Member States shall report the data on mineral or synthetic lubrication or industrial oils placed on the market and waste oils separately collected and treated for each calendar year to the Commission."*

The reporting on waste oils is of great importance, as the Commission by the end of the year 2022 shall use this data to examine the feasibility of developing measures and possible targets for the treatment of waste oils.

The first reference year for data reporting on waste oils shall be the year 2020. The MS must then report the data within 18 months of the end of the reporting (reference) year for which the data is collected, meaning that the first collected data will only be available by mid-2022 (30 June 2022 is the deadline for first data reporting). The official format for reporting of waste oils data was adopted in mid-2019 as an essential basis of the reporting obligation: Commission Implementing Decision (EU) 2019/1004, Annex VI, data on mineral and synthetic lubrication and industrial oils and waste oils referred to in Article 7(3)[16], see Annex I, 27.1.1 and 27.1.2.

The format stipulates obligatory reporting on (waste) oil placed on the market (PoM), its collection and treatment for different lubricant/waste oil categories. In addition, more detailed information on the type of treatment and resulting products is requested.

As important preparatory work for the waste oils reporting, DG Environment commissioned this study to support the Commission in defining reporting obligations on waste oils. In this regard, the consultant supported the Commission in developing the draft data format, which was an iterative process. The following main tasks were performed by the Oeko-Institut:

- Definition of oils placed on the market (based on CN codes);
- Definition of waste oils (based on LoW codes);
- Adaptation of the initial non-paper on a format for reporting data;
- Analysis and assessment of questions from MS on the draft reporting format;
- Check and adaptation of the 'last version' of the draft reporting format.

The reporting format was accompanied by a quality check report, the final version of which is presented in Annex I, 27.1.2. An additional guidance document also had to be developed. The final draft of the guidance document is presented in Annex I.

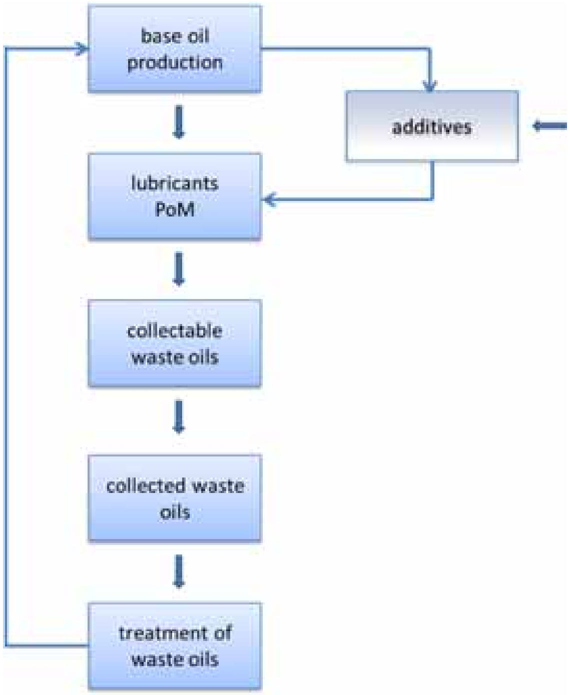
[16] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2019.163.01.0066.01.ENG&toc=OJ%3AL%3A2019%3A163%3ATOC

3 Introduction

Better knowledge in the field of lubricant oils[17] and waste oils is needed in the forefront of the formal reporting on waste oils by Member States. Therefore, this study analyses the situation of oils and waste oils in the EU-28. Quantitative data on relevant material flows of oils and waste oils were gathered, analysed and assessed.

The methodical approach to the material flows of oils is oriented towards the stages of the oil life cycle. Figure 3-1 provides a simplified overview of the oil life cycle with relevance to this study. In the context of waste oil reporting, the very first process stage of crude oil extraction is not relevant and thus excluded from the material flow analysis. With regard to the later generation of waste oil, the lubricant oils placed on the market (PoM) in the EU are relevant (in this simplified figure, the production of lubricant oils is included in PoM). Collectable waste oils do not represent a physical process stage. However, they are relevant for waste oil reporting und thus included in the analysis.

Figure 3-1 Schematic life cycle of (waste) oils



Source: Oeko-Institut

The quantification of material flows is complicated by the fact that at all process stages additional import and export flows as well as potential losses have to be considered. Imports and exports can take place in the form of e.g., lubricant oils or waste oils but also as products which include lubricant oils (for example vehicles including engine oil). Refineries for the production of virgin base oils and re-refineries

[17] In ToR the term "lubricant oils and industrial oils for uses other than lubrication" is used to describe the oils to be considered in this study. In the following, only the term 'lubricant oils' or simply 'lubricants' is applied.

for the regeneration of secondary base oils do not exist in all MS. Consequently, imports and exports between MS must take place.

Different types of losses will also have to be taken into account. Physical and unavoidable losses occur when a fraction of the engine oil is burned during its service life in motors during the use phase of vehicles. Avoidable losses occur, as not all collectable waste oil is actually collected. Export of e.g., used vehicles also means losses of oils for the reporting country.

In the subsequent sections the individual life cycle stages according to Figure 3-1 will be analysed and as a result the qualitative and quantitative information will be explained and assessed. Additives represent a certain share of lubricant oils composition and are at the same time partly derived from base oil, see Chapter 4. While the actual production of the additives is not considered in this study, their mass flows which contribute to the lubricant oils are.

The material flows in Chapters 11 and 12 present and summarise the outcome of the (waste) oil life cycle. However, in order to maintain the focus on the essential results, a (more detailed compared to Figure 3-1, but still) simplified approach is used[18].

The results of this study and in particular of the material flow analysis are based to a large extent on data and information from the stakeholder consultation process. Answers to the questionnaires by Member States (MS survey 2019), GEIR (GEIR 2019) and FuelsEurope/Concawe (FuelsEurope 2019) present the most relevant data sources from stakeholder consultation. In addition, extensive desktop research was performed and, apart from statistics, a great deal of country-specific literature was identified.

[18] For a much more complex presentation, which is better suited to 'real' mass flows, please refer to the example of France in (CPL 2017).

4 Base oils

Most base oils are made of mineral crude oil and result from the refinery process. Base oils are the starting material for the production of lubricant oils. Lubricant oils are produced by blending base oils of different characteristics and by adding additives to the blend. The share and type of additives added to the base oil depends on the application of the lubricant oil. However, there are also applications that do not require base oils to be blended with additives as for example process oils or heat transfer fluids (FuelsEurope 2019); see Chapter 5. Lubricant oils contain about 75% to 80% base oil according to (ERM 2017). French lubricant mass flows confirm a share of about 23% additives in lubricants, whereby a part of the additives originate from base oils (CPL 2017).

The properties of the lubricant oil will depend on the characteristics of the base oils and the additives. The most relevant properties of base oils are: viscosity, high resistance to oxidation, low pour point and good dope susceptibility or compatibility (JRC 2017a).

The American Petroleum Institute (API) has classified base oils into five groups. This categorisation is based on the following main criteria: percentage of saturates, sulphur content and viscosity index. These criteria determine the properties of base oils from above. The API groups and their characteristics are presented in Table 4-1 and are often referred to in this study.

The production of base oil groups IV and V is a synthetic process that takes place in a chemical plant. Therefore, a distinction can be made between mineral (or conventional) base oils originating from a refinery (crude oil) and synthetic base oils from a chemical plant. Bio base oils present another category and are also typically sourced from a chemical plant (FuelsEurope 2019). Furthermore, base oils can be categorised into virgin base oils (mineral, synthetic and bio from refineries/chemical plants) and re-refined (or regenerated) base oils from re-refineries.

Table 4-1 Base oil categories according to API base oil groups

Category	Sulphur content %		Saturates %	Viscosity index	Production
Group I	>0.03	and/or	<90	80 to 120	Mineral, solvent
Group II	<0.03	and	>90	80 to 120	Mineral, hydrotreated
Group III	<0.03	and	>90	> 120	Mineral, hydrocracked
Group IV	polyalphaolefins (PAOs)				Synthetic, chemical plant
Group V	All other base oils not included in Groups I to IV				synthetic

Source: Machinery lubrication 2019

The use of the base oils respectively lubricants is discussed in detail in Table 5-1 and Chapter 5.

4.1 Base oil production capacities and production

The following Table 4-2 shows the EU-wide plant capacities for the production of base oil according to API groups by Member States for the year 2019. Only virgin base oils are considered. The further capacities for the production of re-refined base oil are listed and discussed in detail in Chapter 7.

Table 4-2 Yearly mineral base oil capacities (virgin base oil) in the EU-28; 1000 tonnes/year; 2019

Country	City	Paraffinic, Group I	Paraffinic, Group II	Paraffinic, Group III	Paraffinic, Group IV (PAO)	Naphthenic *	Total
BE	Feluy (a)				70		70
BE	Beringen				63		63
Total BE					**133**		**133**
CZ	Kolin	115				15	130
CZ	Pardubice	80					80
Total CZ		**195**				**15**	**210**
FI	Provoo			250			250
Total FI				250			250
FR	Port-Jerome	626		49			675
FR	Gonfreville	250		39			289
FR	Gravenchon				88		88
Total FR		**876**		**88**	**88**		**1 052**
DE	Hamburg (b)	516					516
DE	Salzbergen (b)	240					240
DE	Harburg (b)					419	419
Total DE		**756**				**419**	**1 175**
EL	Agii Theodori	224					224
Total		224					224

Country	City	Paraffinic, Group I	Paraffinic, Group II	Paraffinic, Group III	Paraffinic, Group IV (PAO)	Naphthenic *	Total
EL							
HU	Szazhalom-batta	198					198
Total HU		198					198
IT	Livorno	600	35				635
IT	Augusta	782					782
Total IT		**1 382**	**35**				**1 417**
NL	Rotterdam		1 000				1 000
NL	Ankerweg				15		15
Total NL			1 000		15		1 015
PL	Gdansk	268					268
PL	Plock	162					162
PL		430					430
PT	Porto	150					150
Total PT		150					150
ES	San Roque	271					271
ES	Cartagena	130					130
ES	Puertollano	80					80
ES	Cartagena**		186	450			636
Total ES		481	186	450			1 117
SE	Nynashamn					400	400
Total SE						400	400
UK	Fawley	407		50			457
Total		407		50			457

Country	City	Paraffinic, Group I	Paraffinic, Group II	Paraffinic, Group III	Paraffinic, Group IV (PAO)	Naphthenic *	Total
UK							
EU total		5 099	1 221	838	236	834	8228

* Made of naphthenic crude oils; base oils with better solubility result.
** Joint venture between SK and Repsol
Sources: 2019 LNG Publishing Co. Inc., Pathmaster Marketing Ltd.; Lubes'n'Greases 2019 Base Stock Guide
(a) https://www.ineos.com/businesses/ineos-oligomers/sites/ download 3.9.2019
(b) MWV 2018

The total capacities for the production of virgin base oil add up to about 8.2 million tonnes in the EU-28. Additional capacities of about 0.95 million tonnes result from re-refining of waste oils, see Chapter 7. The table shows that the capacities are dominated by base oil group I, with about 5.1 million tonnes or 62%. Group II follows with about 1.2 million tonnes (about 15%). Group III is about 0.84 million tonnes (about 10%). It is interesting to note that the API group II plant in Rotterdam with a capacity of 1 million tonnes was only opened this year, 2019, and now presents the largest base oil plant in Europe. Furthermore, additional capacities of about 200 000 tonnes of groups II and III, have been announced for the existing plant in Spain, Cartagena, for next year.

These new capacities already indicate a shift from base oil group I to higher groups II and III. The (future) market trends will be analysed in more detail in the subsequent section.

The yearly production of virgin base oils (excl. re-refined base oils) per Member State is presented in Table 4-3. The total production adds up to about 8 million tonnes per year (based on figures available per Member State corresponding to different years between 2013 and 2018) in the EU-28 (FuelsEurope 2019)[19]. For seven MS it is assumed that no base oil production occurs and no information is available for the remaining MS. A comparison with the EU-28 production capacities in Table 4-2 (year 2019) shows a comparatively high degree of consistency at first sight. The overall production capacity in the EU-28 (about 8.2 million tonnes) corresponds to about 8 million tonnes of (average) production in Table 4-3. However, the capacities already include the new plant in Rotterdam (Netherlands) for the year 2019 with a capacity of about 1 million tonnes of group II base oil. Furthermore, the production figures in the Netherlands (year 2013) include two plants (KPI in Rotterdam and Shell in Pernis) for group I base oil which shut down in 2016 (F+L Daily 2019). Differences also occur for Belgium (missing in Table 4-3) and Croatia (missing in Table 4-2). Additional considerable inconsistencies occur in other MS between production and capacity (e.g. Czech Republic reports 500 000 tonnes production compared to only 210 000 tonnes of capacity). Therefore, the comparison of production and capacity is above all a reflection of the time changes and shows for the Netherlands the shift from base oil group I to group II. Furthermore, a production of about 7.99 million tonnes with a capacity of 8.228 million tonnes corresponds to a capacity utilization of about 97%.

[19] Data is derived from the stakeholder questionnaire answered by FuelsEurope / Concawe who have compiled data from various sources.

This figure appears very high and suggests that the actual production volumes for 2018 / 2019 should be lower than 7.99 million tonnes of base oil.

Table 4-3 Yearly mineral base oil production (virgin base oil) in the EU-28; 1000 tonnes, different years (2013 to 2018)

Member State	Virgin base oil production (1000t/y)	Year
Croatia	17	2017
Czech Republic	500	2013
Finland	330	2013
France	811	Average 2013-2017
Germany	1 355	2013
Greece	235	2013
Hungary	107	2013
Italy	868	2013
Netherlands	1 084	2013
Poland	772	2013
Portugal	127	2013
Spain	900	Average 2017-2018
Sweden	427	2013
United Kingdom	457	2017
EU-28	**7 990**	

Source: FuelsEurope 2019

4.2 Base oil demand and market trends

The demand for the individual base oil groups is changing rapidly. The demand for base oil was long dominated by base oil API group I. Group I accounted for nearly 60% of the global base oil market and group II accounted for about 25% in terms of capacities (Lube 2013). However, group I is being increasingly replaced by base oil groups II and III. According to Arthur D. Little, the global demand for group I base oil is forecasted to decline by about 1% annually (ADL 2015). For group III, a growth rate of about 9% is expected.

The growing importance of synthetic base oils is also confirmed in (Lube report 2018). API Group III reached a global production capacity of 7.3 million tonnes in 2018 (compared to 0.84 million tonnes in the EU-28 in 2019, see Table 4-2). This corresponds to an increase of 72% since 2009. Group IV (PAO) capacity has increased by 51% since 2009 to 713 000 tonnes in 2018 (compared to 236 000 tonnes in the EU-28 in 2019, see Table 4-2). In contrast, global group I base oil production capacity decreased by 20% from 29.2 million tonnes in 2007 to 23.3 million tonnes in 2018

(Lube 2018a). In 2019, global Group II base oil capacity for the first time surpassed that of Group I (LNG Publishing 2019). Group II currently accounts for 40% of the global capacity while Group I accounts only for 37%. Group III has reached 14%.

Kline estimated that the global total demand for base stocks was about 35.5 million tonnes in 2016 (and 39.0 million tonnes of finished lubricants). For Europe, the share of API group I was estimated to be about 48% of the demand in 2016. In comparison, group I has a share of 62% of the EU-28 base oil capacity in 2019, see Table 4-2 and above. Groups II and III accounted for about 13% and 21%, respectively, of the European demand (15% and 10% of the EU-28 capacity in 2019). Furthermore, Kline forecasted the global finished lubricant demand growth at a CAGR (Compound annual growth rate) of 0.5%-1.0% over the next 10 years. For API group I a decline of about 1.7% (CAGR) was estimated for the years up to 2026. At the same time, a growth rate of about 2.5% to 2.7% for group II was estimated and 3.1% to 3.7% for group III (years 2016 to 2021 and years 2021 to 2026, respectively) (Kline 2017).

Higher quality requirements in the automotive sector are considered a main driver for the transition from base oil group I to II in Europe (Lube 2018a). This shift to higher base oil groups is also confirmed e.g., in Lube (2019a) and by FuelsEurope (2019): *"The market for lubricants is changing rapidly. For example, in the automotive sector the need to improve emissions and the addition of exhaust after-treatment requires new higher performing lubricants, and the extension of drain intervals requires new formulations. Over recent years the demand for higher performance from lubricants (in particular life time and frictional performance) has pushed the market towards higher API groups. As demand has changed, so production of base oil has shifted away from group I and towards group II and, increasingly, group III."*

Despite the sharp decline in demand for group I in recent years, this base oil group is still of great importance due to certain properties, in particular its broad viscosity range and solvency. Furthermore, applications like gear oils, hydraulic fluids, greases in machine oils, marine and heavy duty applications still require group I base oils. In particular marine applications require the properties of group I to deliver the necessary engine protection, stable oil life and reduced operating costs (LubesNGreases 2019).

The shift from base oil group I to groups II and III becomes also obvious when comparing the base oil production capacity with the demand pattern in Europe (LubesNGreases 2018). In 2016, there was a European capacity of about 8 million tonnes while the demand for base oil was only about 6 million tonnes. Existing capacities therefore suggest that supply and demand are in line. In fact, however, the current demand patterns no longer correspond to the structure of the capacities built up over the years. Regarding base oil group I the capacity was about two times the actual demand. However, for groups II and III the demand was higher than the capacities.

5 Lubricant oils

The use of lubricant oils is manifold. Generally, two different categories of applications may be distinguished:

- Automotive lubricant oils and
- Industrial lubricant oils.

As regards the chemical type or origin of lubricants, WFD Article 3(3) provides the definition of waste oils: "*'waste oils' means any mineral or synthetic lubrication or industrial oils…".* This definition explicitly mentions mineral and synthetic lubricants but not bio-based lubricants.

Lubricant oils placed on the market can also be categorised into lubricant oils for lubrication and industrial oils for uses other than lubrication (process oils, heat transfer oils etc.; see e.g., Group 8 in Table 5-1). Additional approaches and categories to distinguish lubricants are described in EC-JRC (2018) and a commonly used detailed classification and coding system is applied in CPL (2017).

A detailed approach for categorising lubricant oils according their use is provided in Table 5-1. It considers 10 specific groups of oil applications and is based on products to be reported as placed on the market in Germany (BAFA 2018).

The first three groups of oils can be allocated to automotive oils. However, a smaller share of these oils is also used for industrial applications other than in vehicles. Oil groups 4 to 9 are solely industrial applications and a part is used for applications other than lubrication (e.g. group 5, 6 or 8). Group 9 includes the use of oils which contain mainly water (emulsions) when becoming waste oil.

Table 5-1 Use of oils to be reported as products placed on the market

Group	Term	Products to be reported
1	Engine oils	Automotive motor oils, motor oils for diesel engines in commercial vehicles, gas motor oils, aircraft motor oils, motor oil additives (engine corrosion protection oils), two-stroke oils.
2	Gear oils	An active substance containing automotive gear oils and industrial gear oils as well as power transmission oils for automatic transmissions (automatic transmission fluid; ATF), but no STOU (Super Tractor *Oil* Universal) or UTTO (Universal Tractor Transmission *Oil*) oils, since these belong to the hydraulic oils category (group 3).
3	Hydraulic oils	Hydraulic oil as defined by DIN 51 524. Also: used as hydraulic oil, untaxed engine oils, tipper oils, control oils, shock absorber oils, pressurized water additives (other than those of drilling oil that are included in group 9), universal oils for agriculture used for non-motor purposes (e.g. UTTO and STOU).
4	Turbine oils	Lubricating and control oils L-TD defined by DIN 51 515; steam, hydro and combustion turbine oils
5	Transformer oils/ (electrical) insulating oils	Transformer oils, switch oils and converter oils defined by DIN 57 370; capacitor oils; ground cable and hollow cable insulating oils; however, cable Vaseline is not one of the lubricants.
6	Compressor oils	Air compressor oils, refrigeration compressor oils
7	Machine oils	Mineral oils, which are mainly used for lubrication of machinery and machine parts; Specifically: Cylinder lubricant oils, spindle lubricant oils, machine lubricant oils, lubricant oils AN, B, C and CL, adhesive oils, bed track/ slideway oils, all axle oils, textile machine oils, compressed air engine oils and chain oils; Excluded oils: steam and combustion turbine oils (as listed in group 4), dark oils (to be reported as bitumen or fuel oil), fats are excluded
8	Other industrial oils not used for lubrication	Examples include moulding oils, release agents, (mould) formwork oils, stamping oils for ceramics, gas washing oils, air filter oils, dust binders, heat transfer oils, crack test oils, carrier oils for crop protection / pesticides and printing ink oils; Excluded oils: Melting, winding and impregnating oils, which are categorised among the process oils.
9	Metalworking fluids	The metalworking oils include: hardening oils, water-miscible and water-immiscible metalworking oils and corrosion inhibitors. a.) Hardness oil: includes oils for heat treatment and tempering oils. b.) water-miscible metalworking oils: drilling, grinding, rolling and drawing oils; not included: emulsifying formwork oils (as in group 8, and

Group	Term	Products to be reported
		industrial oils) and press water additives (since these are categorized in group 3 hydraulic oil). c.) Non-water miscible metalworking oils: spark erosion oils, honing oils, grinding oils, cutting oils, stamping oils for metalworking, rolling oils, drawing oils; not included: Crack test oils (as in group 8). d.) Corrosion protection oils: oily anticorrosion agents as well as pasty anticorrosive products; among others spray oils, lubricant oils, underbody protection products; not included: Engine corrosion protection oils (as in group 1), greases with corrosion protection, turbine oils with corrosion protection (as in group 4).
10	Base oils	Unleached base oils which are used or can be used for the manufacture of products of groups 1 - 9 or are supplied as carrier oils to additive manufacturers.

Source: BAFA 2018, translated and adapted by Oeko-Institut

Another three types or groups of oils are not included in Table 5-1. These oils either do not result in any waste oil (see Chapter 6) or do not result in (relevant amounts of) collectable waste oil. A main portion of these oils (process oils) are used in the manufacturing of products for the chemical-technical industry. Since they find their way into products, they can no longer be recovered as waste oils. Others lubricants such as greases cannot be recovered in significant quantities due to the nature of their application. Therefore, it sometimes remains unclear whether these groups of oils are included or not in data on lubricants reported as placed on the market.

The three groups of oils not resulting in collectable waste oil are:

- **Process oils:** Technical white oils, medicinal white oils (only liquid paraffin) factory oils (melting, winding and impregnating oils), light-coloured plasticisers/ dispersants and extender oils such as solvents/ raffinates for the rubber industry for producing synthetic rubber or technical rubber articles (tyres and tubes, seals, mats, V-belts, etc.), extruded profiles, articles made of block polymers, multi-carbon papers, permanently elastic sealants, insulating compounds (sound, heat, moisture), care products (polishing, etc.), production of polyurethane foam.
- **(Lubricating) greases:** Greases based on soap or other thickening agents, regardless of the mineral oil content, incl. synthetic greases; vaseline and greases, which are predominantly bitumen, are generally not included.
- **Extracts from lubricant oil refining:** Residues from lubricant oil refining.

In simple terms, the use of the specific lubricant oil (groups) and their share of the total consumption of lubricant oils in a given country depend on the vehicle fleet and the structure and size of the industrial sector. However, the share of automotive oils does not linearly depend on the number of vehicles. Table 5-2 presents the shares of lubricant uses for Poland, Germany, Belgium, France and Portugal. Generally, the shares of the oil groups of the total use differ between Member States and no average breakdown is applicable.

Engine oils are by far the most relevant lubricant group and can make up about half of all uses. Hydraulic oils represent the second highest share. The lubricant oil groups and their share generally differ between countries. However, this is also due to the fact that the categories applied vary from country to country and that some allocations are difficult. In the case of Germany – where the share of engine oil is considerably lower than in other MS – for example additional base oil (as additives) might have to be allocated to engine oil. For Portugal, some gear oil is included in hydraulic oil, as the two categories could not be clearly separated from each other.

Table 5-2 Use of oils and their shares for selected MS

	2018 Poland	2016 Germany	2016 Belgium	2017 France	2018 Portugal	2017 Italy
Engine oils	46.3%	26.6%	57.6%	42.5%	49.1%	39.8%
Gear oils	9.1%	11.7%	15.0%	10.3%	6.4%	9.7%
Compressor oils	1.0%	0.7%	1.7%	0.5%	2.1%	0.9%
Turbine oils (excl. aviation)	1.6%	0.2%	1.2%	0.5%		1.8%
Hydraulic oils	14.9%	10.1%	18.5%	14.5%	20.5%	15.9%
Transformer oils/ (Electrical) insulating oils	0.2%	1.1%	0.2%	1.7%	2.1%	0.0%
Machine oils	3.5%	3.4%	3.6%			8.0%
Machining oils (metal working)	0.2%	7.7%	2.3%	9.4%	3.8%	10.6%
Other industrial oils not for lubrication	1.6%	6.4%		2.4%		3.1%
Other automotive	5.1%					
Other motor oils (e.g. aviation)				1.1%		
Other industrial oils	11.1%			3.8%		
Others	1.5%				0.7%	
Extracts from lubricant oil refinery		1.8%				
Base oils		12.4%			0.3%	
Greases	3.3%	2.9%		4.5%	2.4%	2.8%
Process oils	0.7%	14.8%		8.7%	7.9%	7.4%
Total	100%	100%	100%	100%	100%	100%

Source: POPHIN 2018, UBA 2016, Belgium 2017, CPL 2017, Sogilub 2018, Conou 2017, compiled by Oeko-Institut

5.1 Lubricant oils placed on the market

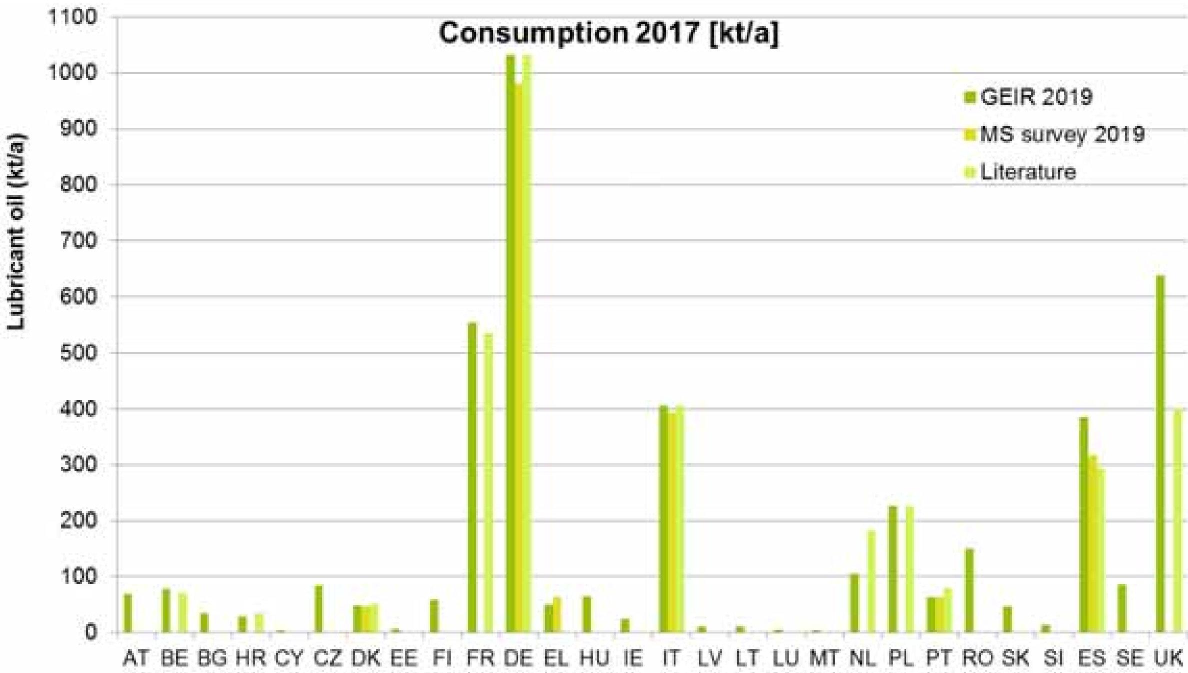
Data on oils placed on the market is available from GEIR (GEIR 2019)[20], 12 MS from the survey[21] (MS survey 2019) and many other sources from the desktop research.

[20] GEIR data excl. emulsions; collected waste oil incl. 6% water; consumption excl. marine oils but usually incl. process oils.

This extensive database, which also contains data on collectable waste oils, collected waste oils and waste oil treatment, is presented in full in Table 27-4 in the Annex. Data is presented by MS, mainly for the years 2014 to 2018.

An analysis of the lubricant oil consumption in the EU-28 follows in Figure 5-1 for the year 2017. Germany, with about 1 million tonnes of lubricant oils, has the highest consumption of all MS and placed about one fourth of the total amount of oils on the market. Germany, the UK, France, Spain and Italy (in order of decreasing consumption) are the main consumers in the EU-28 and together comprised about 71% of the total market consumption. In total, about 4.28 million tonnes of oils were placed on the market in the EU-28 in 2017[22].

Figure 5-1 Consumption of lubricant oils by MS in tonnes, year 2017



Source: GEIR 2019, MS survey 2019, literature sources see Table 27-4 in the Annex

Generally, the scope of the different data sources is not always clearly described and thus makes a comparison and analysis of differences difficult. An explanation for the different figures of Spain is that in the Spanish figures of SIGAUS (Sigaus 2017), at 295 143 tonnes, in contrast to the GEIR data showing 419 000 tonnes, process oils and greases are not included. Differences also occur for Greece (about 64 000 tonnes (MS survey 2019) compared to 50 000 tonnes (GEIR 2019)) and can be explained by about 14 000 tonnes of marine oils included in the figure from the MS survey but not in the GEIR data. Further differences which might in general be explained by different scopes of the data sources also occur for other reporting years and countries, e.g. also for Belgium. At the same time, a comparison of the figures from the different sources

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[21] Data from the MS questionnaires are presented for 10 MS (Czech Republic, Denmark, Estonia, Germany, Greece, Italy, Latvia, Portugal, Slovakia and Spain). Two additional MS also provided data, however, this data has not been authorised for publication in this study.

[22] GEIR is the only data source which covers all MS. Therefore, shares and EU totals are based on GEIR data.

shows that often the principle sources, GEIR, MS survey and literature from the desktop research are based on the same original data source. This applies for consumption and also for waste oil collection data.

The total amounts of lubricant oils placed on the market for EU-28 in 2014, about 4.254 million tonnes, and 2018, about 4.247 million tonnes, are similar to the figure of the year 2017 from above and no clear trend is visible. Also the share of the specific MS of total EU demand differ if at all only slightly. The five main consumers (Germany, the UK, France, Spain and Italy) together had a respective demand of about 71% (2014) and 70% (2018) of the total lubricant oil consumption.

5.1.1 Bio lubricant oils

Bio lubricant oils account for only a small proportion of the total lubricant oils. In Europe[23] bio lubricant oils made up about 3% of the total lubricant oils (incl. process oils) placed on the market in 2015. An increase to about 4% by 2022 is estimated. Table 5-3 presents the applications of bio lubricant oils and the share of the applications of the total use of bio lubricant oils in 2015. About 88% of the bio lubricant oils is based on vegetable oil and the remaining 12% is based on animal oil.

Table 5-3 Applications of bio lubricant oils in Europe; year 2015

	2015
Automotive oils	26%
Hydraulic fluids	21%
Process oils	21%
Demoulding oils	11%
Lubricating Grease	9%
Chainsaw oil	6%
Compressor oil	2%
Turbine oil	2%
Industrial gear oil	1%
Metalworking fluids	1%
Total	100%

Source: EC-JRC 2016

As stated above, bio lubricant oils are not included in the WFD definition of waste oils and thus are also not considered in the mandatory reporting of waste oils. The official format for reporting of waste oils data was adopted in mid-2019: *Commission Implementing Decision (EU) 2019/1004, Annex VI, data on mineral and synthetic lubrication and industrial oils and waste oils referred to in Article 7(3)*[24]. Relevant

[23] Total Europe, no data is available specifically for EU-28.

[24] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2019.163.01.0066.01.ENG&toc=OJ%3AL%3A2019%3A163%3ATOC

amounts of the bio lubricants placed on the market do not result in waste oils, e.g. process oils or chainsaw oil. Therefore it is reasonable to not include bio-based lubricants in the reporting. Furthermore, statistical data on lubricant oils PoM often rely on mineral oil data (e.g., in Germany) and thus should not include bio lubricant oils. Uncertainty still remains as to whether MS data include bio lubricant oils and waste oils from bio lubricants. However, given the low share of bio lubricant oils and the already existing inaccuracies in the data on lubricant oils, it can be assumed that potential inconsistencies caused by bio lubricants should not be significant.

5.1.2 Marine oils

Global marine oil consumption accounted for about 1.58 million tonnes in 2012. About 65% was used as cylinder oil; about 26% was used as trunk piston engine oil and the remaining 9% as system oil. Europe's share of the total marine oil was about 32% or about 0.5 million tonnes in 2012 (LubesNGreases 2014). For the EU-28 we estimated about 0.35 million tonnes of marine oil for 2012 based on the MS shares of the total European lubricant oil demand in 2017 (Fuchs 2018a). Growth in global consumption of marine oils of yearly 1.3% is estimated for the years up to 2022.

The generation and collection of bilge oils resulting from marine oils is influenced by international shipping traffic. In a port, the distinction between the national and international origin of the marine oil in the collection of the bilge oil is expected to be difficult. Therefore, amounts placed on the market and collected are expected to differ for a given country, and only voluntary reporting of bilge oils is foreseen in Commission Implementing Decision (EU) 2019/1004, Annex VI.

5.2 Market developments

The European lubricant oil demand (excl. marine oils) has decreased from about 8.4 million tonnes in 2007 to about 6.8 million tonnes in 2017 (Fuchs 2018a). This corresponds to a decline of about 17%. A main reason for the decline in oil demand, apart from the economic crisis in 2008/2009, is the lower consumption of engine oil. Oil change intervals are becoming longer and longer and engine oil losses from the burning of engine oil during driving are decreasing (less "topping-up" to compensate for losses). In 2018, the demand slightly increased and reached about 6.9 million tonnes in Europe (Lube 2019b). For economic market aspects please refer to Section 14.

Detailed information on European lubricant oils market volumes with a forecast up to 2022 are provided in (EC-JRC 2016). Data for the starting year 2015 is estimated and forecast data is based on growth rates for the specific applications. The overall market volume of Europe is estimated to be about 7.4 million tonnes in 2015. In 2022 the European market volume reaches about 8.3 million tonnes; an increase of about 12% between 2015 and 2022 (about 1.7% yearly). Based on these European figures estimates for EU-28[25] were calculated and are listed in Table 5-4.

[25] EU-28 was calculated based on an estimated share of 70% of the total European figures. Our own estimate of 70% is based on the shares of MS of the total European lubricant oil demand in 2017 (Fuchs 2018a).

Table 5-4 Estimated lubricant oil market volumes EU-28 in million tonnes, forecast 2016 to 2022

Estimates EU-28, million tonnes	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
Industrial process oils	0.81	0.82	0.83	0.85	0.87	0.88	0.90	0.92	1.9%
General industrial oils	0.83	0.84	0.85	0.87	0.88	0.90	0.92	0.93	1.7%
Metalworking fluids	0.34	0.34	0.35	0.36	0.36	0.38	0.39	0.39	2.1%
Industrial engine oils	0.28	0.29	0.29	0.30	0.31	0.32	0.32	0.33	2.1%
Other industrial lubricants	0.30	0.30	0.31	0.32	0.32	0.32	0.33	0.34	1.8%
Commercial automotive lubricants	1.37	1.39	1.40	1.41	1.44	1.45	1.48	1.50	1.2%
Commercial automotive HDEO	*0.78*	*0.79*	*0.80*	*0.81*	*0.83*	*0.83*	*0.85*	*0.87*	*1.4%*
Commercial automotive HTF	*0.27*	*0.27*	*0.27*	*0.27*	*0.27*	*0.28*	*0.29*	*0.29*	*1.3%*
Commercial automotive gear oil	*0.27*	*0.27*	*0.27*	*0.27*	*0.27*	*0.27*	*0.27*	*0.28*	*0.7%*
Commercial automotive grease	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*1.0%*
Consumer automotive lubricants	1.20	1.22	1.23	1.25	1.27	1.30	1.32	1.37	1.5%
Passenger vehicle & motor oil	*0.88*	*0.89*	*0.90*	*0.92*	*0.93*	*0.95*	*0.97*	*0.99*	*1.6%*
Consumer automotive ATF	*0.13*	*0.13*	*0.13*	*0.13*	*0.13*	*0.13*	*0.13*	*0.14*	*1.4%*
Consumer automotive gear oil	*0.16*	*0.16*	*0.16*	*0.16*	*0.16*	*0.17*	*0.17*	*0.18*	*1.2%*
Consumer automotive grease	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*1.2%*
Total	5.1	5.2	5.3	5.4	5.5	5.5	5.6	5.8	
Total excl. process oils, grease	4.2	4.3	4.3	4.4	4.5	4.6	4.6	4.7	

Source: EC-JRC 2016; original data for Europe; EU-28 estimated by Oeko-Institut

The calculated figures in Table 5-4 result in about 5.1 million tonnes of lubricant oils PoM in the EU-28 in 2015 and increase yearly by about 0.1 million tonnes. The EU-28 consumption figures presented in Chapter 5.1 are clearly smaller: about 4.23 million tonnes (2014), 4.28 million tonnes (2017) and 4.24 million tonnes (2019). Furthermore, the figures do not display a trend towards increasing consumption.

In the automotive sector due to the emergence of electric vehicles, a decline in the demand for lubricant oil is generally expected for the future. Overall, a reduction of the global lubricant oil demand of 2% to 3% in 2030 is expected according to (Lube 2019b). However, the European market is expected to be much more effected by the shift towards electric vehicles, and a reduction of the total lubricant oil demand of about 20% in 2030 is estimated. Apart from automotive oils, metalworking fluids are also affected. As electric vehicles have about 80% fewer components, the total demand for fluids for metal processing is estimated to decrease by about 30% by 2030 in Europe.

The future market developments of global lubricant oil demand are also described in McKinsey (2019) and presented in Table 5-5. For the automotive sector, results similar to other sources foresee a slight increase in lubricant demand from 17.2 million tonnes in 2017 to 17.4 million tonnes in 2020. Thereafter, the demand in the automotive sector is expected to steadily decline and reach 15.9 million tonnes in 2035 (annual growth rate of -0.8%; 2025 to 2035). However, overall global lubricant demand is estimated to increase from 42.7 million tonnes in 2017 to 48.8 million tonnes in 2035 (annual average growth of 0.8%) and is based on the growth of the non-transport / industrial sector (annual growth rate of 1.5% from 2017 to 2025, and 1.2% from 2025 to 2035).

Table 5-5 Global lubricant oil demand by sector in million tonnes and %, forecast 2017 to 2035

	2017	2017	2020	2020	2025	2025	2030	2030	2035	2035
Units	[mill. t]	[%]	[mill. t]	[%]	[mill. t]	[%]	[mill. t]	[%]	[mill. t]	[%]
Road Transport/ automotive	17.2	40	17.4	39	17.3	37	16.9	35	15.9	33
Non-transport/ industrial	22.7	53	23.8	54	25.6	55	27.2	57	28.9	59
Other transport (marine, aviation, rail)	2.8	7	3.0	7	3.4	7	3.7	8	4.0	8
Total	42.7	100	44.2	100	46.3	100	47.8	100	48.8	100

Source: McKinsey 2019

Lubricant oils in the automotive sector constitute about half of the total lubricant demand. Significant changes in the automotive sector will particularly in the EU lead to significant changes in the demand in this sector and also total demand. While the population is expected to further grow and a potential increase in personal mobility will increase the demand for lubricant oils in the near future, other developments will lead to a decrease in the longer term. One major change expected in the coming decades is the increase of hybrid and battery-powered vehicles. This will make some lubricants obsolete that are used today, i.e., engine oils, gear oils, but will also require the development of new lubricants. Table 5-6 provides an overview of anticipated changes in the use of lubricant oils for different application in different types of vehicles.

Table 5-6 Anticipated changes in the use of lubricant oils in vehicles

Applications	ICE	Hybrid (HEV / PHEV)	Battery (BEV)
Engine oil	R	R	NR
Transmission oil	R	R	R / NR
Greases	R	R	R
Specialty greases	R	+	+
Lubricants for auxiliary systems	R	+	+
Cooling and functional liquids	R	+	+

ICE= internal combustion engines; R=required; NR=no longer required; +=increasing

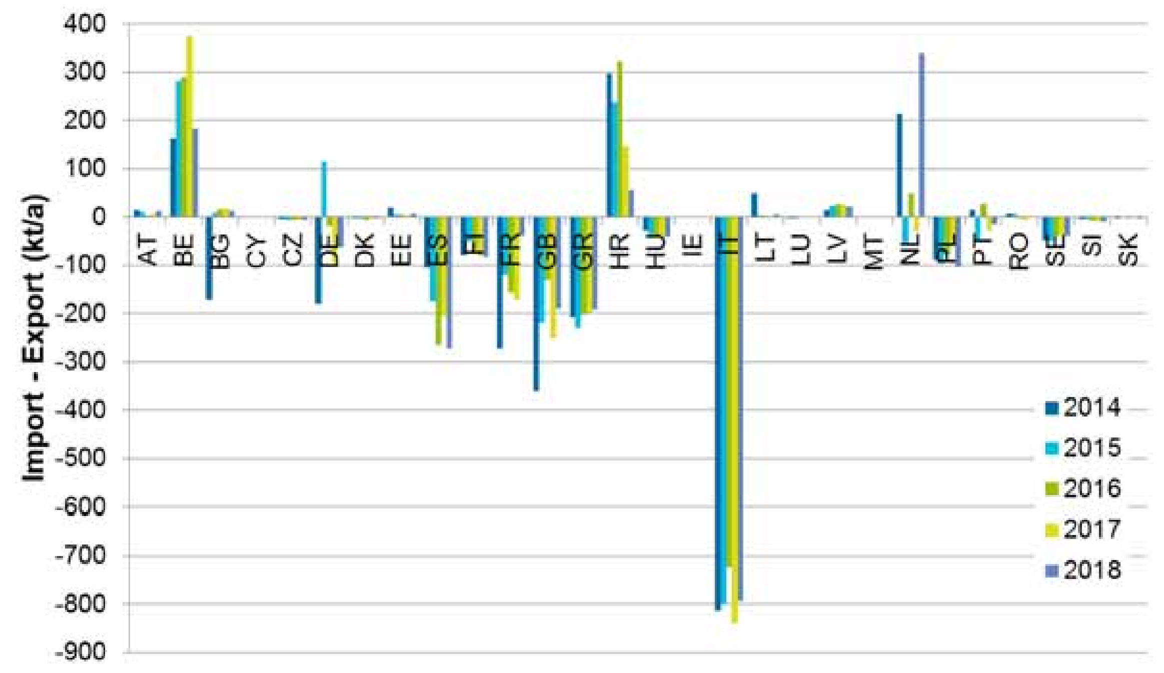
Source: Fuchs 2018b

5.3 Imports and exports of lubricants

Figure 5-2 presents the Member States' extra EU trade[26] of lubricants. The differences between imports and exports (negative figures indicate a net export of lubricants) are shown for the years 2014 to 2018. Considerable net imports of lubricants over several years took place in Belgium, Hungary and the Netherlands. Apart from that, net exports outside the EU by far outweigh the net imports. The net exports are dominated by Italy. Overall, the EU-28 is a net exporter of lubricants. Between 2014 and 2018 fluctuating amounts of lubricants between 0.98 million tonnes and 1.56 million tonnes were exported (net export) outside the EU. Italy's share accounts for more than half of all net exports.

[26] Statistics on **extra-EU** trade are calculated as the sum of trade of each of the 28 MS with countries outside the EU. Trade flows are measured into and out of the EU, but not among EU Member States. **Intra-EU**, on the other hand, refers to all transactions occurring within the EU. The term can have a different coverage, depending on the perspective taken: the EU as a whole, a Member State, ...The exports of a particular Member State, for instance, can be split into two parts, on the one hand to the countries outside the EU, the rest of the world, 'extra-EU', and on the other to the other Member States, 'intra-EU'.

Figure 5-2 Extra EU-28 trade (imports–exports) of lubricants; years 2014 to 2018, 1000 t, (negative figures = net export)



Source: Eurostat COMEXT, codes 27101971, 27101975, 27101981, 27101983, 27101987, 27101991, 27101993, 27101999, 27139090, 34031910, 34031980; extracted 14.5.2019

An analysis of intra-EU[27] trade of lubricants was also carried out on the basis of Eurostat's COMEXT database, see Table 27-3 in the Annex for detailed results of intra-EU and extra-EU trade of lubricants. It would be expected that imports and exports within the EU (from one MS to the other MS) would balance each other out to a net zero. However, this is not the case and statistical asymmetries result. For various reasons (e.g., a threshold for reporting, statistical outliers, confidentiality reasons), values are considered more reliable than quantities (the latter are often estimated) and methodological aspects (Comext 2019). The consideration of intra-EU trade of lubricants on a detailed level must therefore be carried out with caution and can be meaningful for some MS while not for others.

As shown in Figure 5-2, Italy is the main net exporter (extra-EU trade) of lubricants with about 0.79 million tonnes in 2018. At the same time, base oil production capacities (about 0.87 million tonnes virgin base oil and about 0.14 million tonnes re-refined base oil) are much higher than the consumption of lubricants in Italy; 0.40 million tonnes. Thus, a difference between base oil capacity and lubricant consumption of about 0.61 million tonnes occurs. This figure is similar to the net export of 0.79 million tonnes in 2018. The remaining difference of 0.18 million tonnes is rather small, taking general inaccuracies into account. Italian's intra-EU trade does not support

[27] Statistics on **extra-EU** trade are calculated as the sum of trade of each of the 28 MS with countries outside the EU. Trade flows are measured into and out of the EU, but not among EU Member States. **Intra-EU**, on the other hand, refers to all transactions occurring within the EU. The term can have a different coverage, depending on the perspective taken: the EU as a whole, a Member State, ...The exports of a particular Member State, for instance, can be split into two parts, on the one hand to the countries outside the EU, the rest of the world, 'extra-EU', and on the other hand to the other Member States, 'intra-EU'.

further clarification considering the inconsistencies described above. Italian's intra-EU trade figures vary between a net import of about 30 000 tonnes (in 2018) and maximum net export of about 90 000 tonnes of lubricants (years 2014 to 2018).

Overall, a virgin base oil production capacities of about 8.2 million tonnes in the EU-28, an additional capacity of about 0.95 million tonnes of re-refined base oil and a production of less than 8 million tonnes of virgin base oil and about 0.67 million tonnes of re-refined base oil (see Chapters 4 and 7) stand in contrast to a lubricant demand in the EU-28 of about 4.3 million tonnes (year 2017, see Chapter 5.1). Therefore, a resulting extra-EU net export of lubricants as described above is reasonable. An extra-EU net export of about 1.5 million tonnes of lubricants in 2017 seems to be rather small. However, net exports can take place both for lubricants and base oils and thus can explain the difference between production (base oil) and demand (lubricant) in the EU.

When adding the net export of about 1.5 million tonnes to the consumption of about 4.3 million tonnes of lubricant oils in 2017, a total production of about 6.1 million tonnes results for the EU-28. Based on a content of 23% additives (about 1.4 million tonnes) in lubricant oils, the production of 6.1 million tonnes requires about 4.7 million tonnes of base oils. The difference between about 8.7 million tonnes of base oil production (virgin and re-refined) and 4.7 million tonnes for the lubricant production in the EU-28 results in an amount of about 4 million tonnes of base oil. The largest part of this difference can be allocated to a net export of base oil. The remaining part of the difference is used for additives production. These base oil and lubricant mass flows are shown in Figure 12-2.

These estimates are based only on mathematical calculations. Since no concrete, systematic data on base oil exports and additives is available, the estimates cannot be better quantified and verified.

6 Collectable waste oil and return rates

Whether oil placed on the market becomes waste oil after use depends on the specific application of the oil. A certain amount of oil might be lost and only the remaining share will be available for collection as waste oil. In this sense, we refer to 'unavoidable losses' and 'collectable waste oils'. The share of oil placed on the market which is collectable is identical with the 'return rate'. A detailed consideration of the return rate is given in Chapter 6.2 and Chapter 11.1, where the calculation for the engine oil return rate and losses is described in detail.

In practice, the actual collected amount of waste oil might be smaller than the amount of collectable waste oil. Thus, additional losses referred to 'avoidable losses' will potentially occur. In this section, collectable waste oil and avoidable losses will be considered, while the actual collected waste oil will be dealt with in Chapter 8.

6.1 Avoidable losses

Avoidable losses can only be indirectly addressed in this study. Neither the stakeholder consultation nor the desktop research provided any concrete quantitative data on avoidable losses.

Potentially illegal activities or improper management of waste oils which can result in such losses of waste oil are, e.g. engine oil changes by private individuals or the burning of waste oil in small waste oil burners for heating purposes. Losses due to the burning of waste oils in small combustion plants, in particular in service stations, garages, but also in households, as well as losses due to burning in small waste oil incineration plants, which are not registered as energy recovery or waste disposal plants are confirmed in MS survey 2019.

Greece's answer to the MS questionnaire also mentions illegal collection due to the commercial and calorific value of the waste oil. Such illegally collected waste oil can be used as fuel and thus is lost for regeneration (and not taken into account as collected waste oil). Furthermore, it was stated that waste oils have been collected together with petroleum residues (e.g. residues from fuel tank cleaning) and thus are not included in collected waste oil. It is expected, that improved control mechanisms would result in reduced losses and higher amounts of re-refined base oils. (MS survey 2019)

Furthermore, a certain smaller amount of waste oil will also end up in oily sludge or oily waters[28]. As the actual amount of waste oil in these wastes cannot be identified, these wastes are not included in collected waste oils (see Chapter 8 and Table 27-2 in the Annex for LoW codes accounting for collected waste oil). It also cannot be ruled out that waste oils may be assigned the wrong LoW code and are thus not reported as 'collected', but rather appear as a loss.

In principle, such losses from oily sludge, etc. should already be taken into account as unavoidable when determining the collectable waste oil. In practice, however, the actual scope of the data on collectable waste oil remains rather unclear. Therefore, the data can primarily confirm the existence of losses and give a rough idea of the size of the losses.

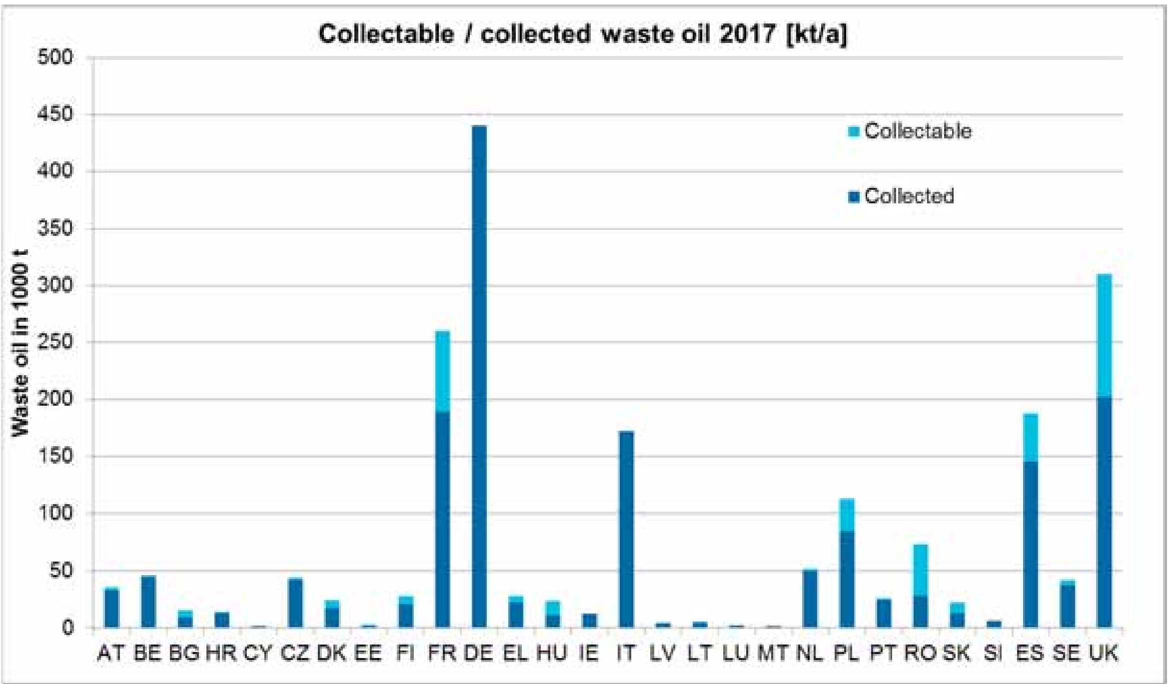
[28] E.g., LoW codes '120118* metal sludge (grinding, honing and lapping sludge) containing oil' or '130507* oily water from oil/water separators'.

Although no actual data on avoidable losses exist, these losses can be derived mathematically. Losses can be calculated by subtracting the actually collected waste oil from the collectable waste oil[29]. With this theoretical approach, however, possible failures due to an unclear scope of the data (on collectable waste oil) and inconsistencies as discussed below (see Section 6.3) must be considered.

Figure 6-1 presents the calculated avoidable losses for the EU Member States in the year 2017. The differences between collectable and actual collected waste oil are shown in the figure as the difference between the two overlapping bars.

For the year 2017, total avoidable losses for the EU-28 of about 0.36 million tonnes were calculated. For comparison, total losses in 2014 were only about 0.21 million tonnes (0.35 million tonnes in 2018). Since there are no known reasons for such an increase in losses from 2014 to 2017, the different quantities are rather an expression of the inaccuracy of the approach and the data.

Figure 6-1 Difference of collectable and collected waste oil by MS; year 2017



Source: GEIR 2019

The data on the losses do not allow any conclusions to be drawn as to whether the waste oil losses actually lead to concrete pollution of the environment (oil-contamination of soil and water).

[29] The share of the actual collected waste oil of the collectable waste is the collection rate; see Chapter 8, Figure 8-2.

6.2 Derivation of return rates

Table 6-1 presents return rates from selected literature sources for different uses of oils according to Table 5-1 and Table 5-2. The derivation of return rates and transparency differ greatly between the individual data sources. In UBA (2016), the methodology applied is described in detail and is comprehensible; in UNEP (2012), essentially only generic values are presented. There are also differences between the sources in the scope. For example, UBA (2016) includes engine oil losses from the export of vehicles, whereas this is not the case with CalRecycle (2012). A more extensive overview of return rates with further literature sources can be found in CalRecycle (2012) and Elsevier (2015).

Return rates for a given group of oils will normally differ between Member States. Return rates of engine oils for example depend on, e.g. the vehicle fleet (size and type of vehicles), vehicle kilometres and oil change rate. In Bulgaria for example, cars between the ages of 15 to 20 years and more represent 62% of the total number of registered cars (Lube 2016). Given the age of the Bulgarian car fleet, it might be expected that the specific engine oil consumption (unavoidable losses) in Bulgaria is higher than in other MS and thus the return rate and the collectable waste oil should be lower.

Return rates of engine oils in Table 6-1 differ considerably between Germany and Belgium. More details on engine oils and their collection and losses are provided in Chapter 11. Belgium return rates are generally higher than German rates (exemptions are hydraulic oils and machine oils). The Belgian (Valorlub 2017) and German (UBA 2016) return rates were calculated in two separate studies. The influence of the applied calculation methodology on the actual return rates remains unknown. For other applications, the return rates show good consistency; e.g. for gear oils (with the exception of UNEP 2012) and hydraulic oils.

Table 6-1 Collectable waste oils – return rates (%) of different oil applications

return rate %	Belgium (Valorlub 2017)	Germany (UBA 2016)	California (CalRecycle 2012)	UK (DEFRA 2006)	General (UNEP 2012)
Engine oils		51.9%		75%	85%
*passenger cars**	*68.3%*		*85%*		
*commercial & industrial vehicles (excl. marine and aviation)**	*72.5%*		*79%*		
*other engine oils**	*72.0%*		*41%-85%*		
*marine engine oils (national)**	*79.2%*		*0%*	*10%*	
Compressor oils	77.2%	50.0%	-	-	30%
Turbine oils (excl. aviation)	90.0%	70.0%	-	75%	70% - 80%
Gear oils				80%	
*automotive**	*82.2%*	*76.1%*	*83%*		*30%*
*ATF**	*85.0%*	*76.1%*	*88%*		*50%*
*industrial**	*86.6%*	*75.0%*	*-*		*20%*
Hydraulic oils	70.7%	75.0%	75% - 90%	80%	

return rate %	Belgium (Valorlub 2017)	Germany (UBA 2016)	California (CalRecycle 2012)	UK (DEFRA 2006)	General (UNEP 2012)
*automotive**					*80%*
*engineering industries**					*20%*
*petroleum industries**					*80%*
*other industries**					*10%*
Transformer oils/ (Electrical) insulating oils	95.5%	90.0%	87%	95%	-
Machine oils	34.1%	50.0%	-	50%	-
Machining oils (metal working)		45.0%	0% - 90%	20%	-
*quenching oils**	*55.0%*				-
*neat oil**	*55.0%*			*20%*	-
*soluble oils**	*60.0%*			*20%*	-
Base oils		50.0%	-	-	-
Process oils		0%	0% - 9%	0%	-
Greases		0%	0%	10%	-
Other industrial oils not for lubrication		0%	-	10%	-
Extracts from lubricant oil refinery		0%	-	-	-

*: subcategory or more detailed category from the row above

ATF: automatic transmission fluid

Compilation by Oeko-Institut

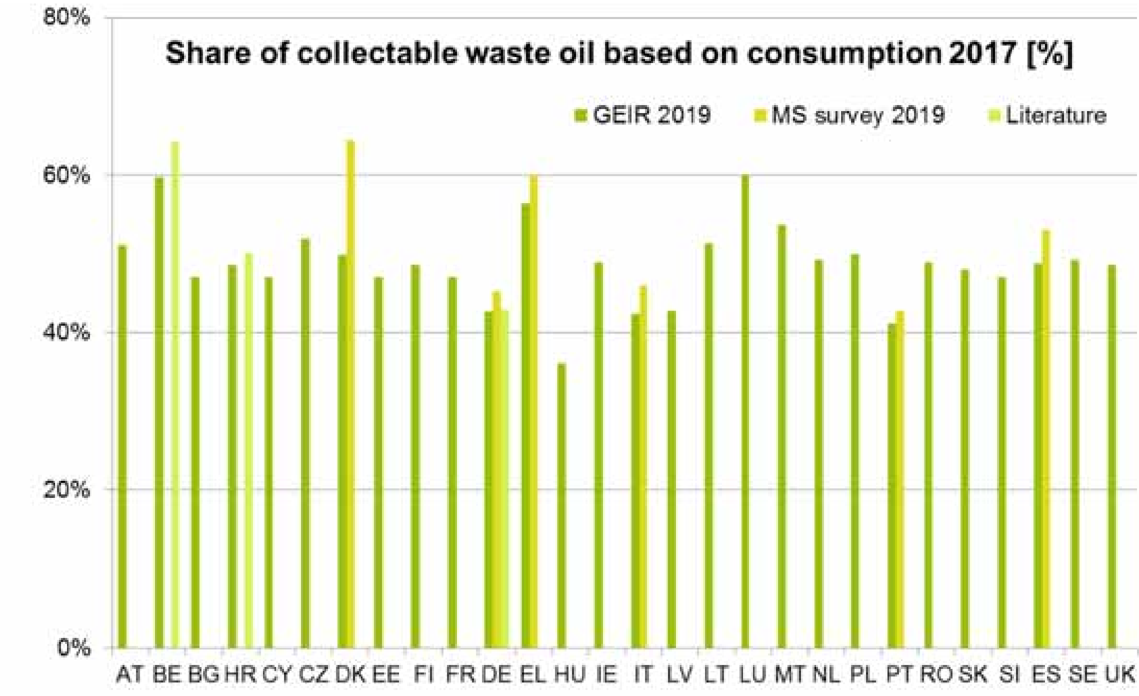
6.3 Share of collectable waste oil

Return rates[30] of all MS calculated from total lubricant consumption and total collectable waste oils are presented in Table 6-2 for the years 2014 to 2018. Figure 6-2 presents an overview of the MS return rates (as reported) for the year 2017. The data for the year 2017 in Figure 6-2 shows that return rates are typically about 50%. Some MS, including Belgium, Denmark and Luxembourg, have higher rates of 60% and more. Rates of about 40% and less occur for example for Portugal or Hungary. Considerable differences between the data sources are in particular visible for Denmark (GEIR reporting about 50% and MS survey about 64%). The deviations might be due to emulsion (not included in GEIR data but included in MS survey data) and due to differences in the specific return rates used for the modelling of the overall return rate. In Table 6-2, return rates typically range from about 40% to 60%. Only return rates for Belgium (up to 72%), Croatia (but only the GEIR figure for 2014, 67%) and Denmark (up to 65%) are higher than 60%. For two more MS, Greece and

[30] Return rates (collectable waste oil divided by consumption) are calculated based on dry oil; for better comparability, the water content (6%) was subtracted for the GEIR figures.

Luxembourg, the figures are higher than 54% (between 56% and 60%). In the following, return rates of some MS are analysed in more detail.

Figure 6-2 Share of collectable waste oil (%) based on consumption by MS, year 2017



Return rates (share of collectable waste oil) calculated based on dry oil.

Sources: GEIR 2019, MS survey 2019 and literature, see Table 27-4

When the specific return rates of Belgium in Table 6-1 are applied to Belgium figures of oils placed on the market (see Chapter 5.1), an overall return rate of about 72% results. This is in accordance with the return rate[31] based on Belgium (2017). This return rate is higher than the return rates of 45% to 62% reported in GEIR (2019) in Table 6-2. However, the Belgium consumption figures in Chapter 5.1 and in Belgium (2017) do not include oils not becoming waste oils (e.g. process oils).

When the specific return rates of Germany in Table 6-1 are applied to German figures of oils placed on the market (see Chapter 5.1 and return rates based on BAFA and UBA 2016 in Table 6-2), overall return rates of 43% and 44% result. These figures are very similar to the other return rates of Germany, 42% to 46%, based on other sources in Table 6-2. However, excluding process oils and greases would result in considerably higher overall return rates for Germany of 52% to 55%.

That the overall return rate of a country is generally a mathematically derived model value is illustrated by the example of Germany. When the collection rate for Germany is calculated from the collectable amount and the actually collected waste oil, a collection rate of more than 100% results (see Chapter 8, Figure 8-2), i.e. more waste oil is collected than would actually be collectable according to the return rate. Reasons

[31] With the exception of the year 2017, return rate of about 64%.

for the incompatibility between the two approaches of the overall return rate and the waste oil quantities based on waste statistics can be manifold: different scopes of PoM and waste statistics, incorrect calculation of the water content of the waste oil, failure to calculate the specific return rate for individual applications, etc.

In Greece, to calculate the collectable waste oil, a return rate of 60% has been applied since 2016. However, the amount of collectable waste oil is considered to be overestimated and the specific return rates for various lubricant applications might not have been identified precisely. It seems that for the year 2017, return rates of 60% for vehicle engine, gear box oils and industrial oils, and 30% for the marine oils were applied (MS survey 2019).

Including marine oil, an overall return rate of about 53% results for Greece in 2017 and a return rate of 60% results when marine oil is excluded. Thus, a difference of about 7% results depending on whether marine oil is included or not. The modelling of engine oils in Chapter 11 results for Greece in a return rate of about 51%, see Table 11-1. This compares to a return rate of 60% for vehicle engine, gear box oils and industrial oils as mentioned above. The different approaches show that considerable differences for the return rate can occur depending on the applied data base and methodology.

The specific data for Italy in Table 8-5 allow an analysis of the effect of the process oils, greases and other oils not for lubricating. While a return rate of about 46% results when process oils, etc. are excluded, the collectable amount of waste oil is about 5% lower (about 41%) when they are included.

For some MS, see examples above, the scope of data and the applied approach for the calculation of the return rate is known. However, for many other MS the applied methodology remains unclear.

The collectable amount of waste oil is generally a calculated / modelled figure. The country-specific collectable waste oil values mainly depend on the specifics of the vehicle fleet (see Chapter 11), the structure of the industry and imports/exports of lubricants within product types (in particular vehicles). Country-specific collectable waste oil should be calculated on the detailed level of the specific lubricant applications and their respective return rates as in Table 6-1.

Engine oils which present by far the most relevant share of all lubricant oils are discussed and presented on a country specific level in Chapter 11. The influence of relevant drivers and resulting return rates are shown in Table 11-1. Engine oil return rates are similar to the overall return rates in Table 6-2 and show that even for a specific oil application return rates differ considerably between countries. Furthermore, return rates based on the data of GEIR 2019 show for some MS differences between the individual years (mainly between 2014 and 2017). These differences might be due to changes in the sectors considered (e.g. growth of a specific industrial sector) or simply due to inconsistencies in the applied methodology.

In order to make the amounts of collectable waste oil and the overall return rates more comparable between MS, a structured approach with the same calculation methodology for each MS would be required (e.g. incl. import/exports, modelling on the detailed level of specific lubricant applications, use of specific return rates ideally generated specifically for each MS). Otherwise a comparison of MS specific collectable waste oils and overall return rates is only meaningful to a limited extent. Potential inconsistencies or inaccuracies of the overall return rates in Table 6-2 (apart from a calculation method that is anyway not identical) might result from, for example, the inclusion or exclusion of process lubricants, other oils not producing waste oils, greases or emulsions; the inclusion or exclusion of water content; calculation of return rates not on the detailed level of specific lubricant applications but instead one (or more) general unspecific return rates; and use of default values for return rates based on UBA (2016) instead of MS-specific rates.

In general, the many influencing parameters and challenges for an individual calculation of country-specific return rates suggest that their use as an indicator or a potential target is not appropriate.

Table 6-2 Share of collectable waste oil (%) by MS

MS	Source	2014	2015	2016	2017	2018
AT	GEIR 2019	47%			51%	52%
BE	GEIR 2019	45%			60%	62%
BE	Belgium 2017	72%	72%	72%	64%	
BG	GEIR 2019	38%			47%	49%
HR	GEIR 2019	67%			49%	49%
HR	Croatia 2017	50%	50%	50%	50%	
CY	GEIR 2019	47%			47%	47%
CZ	GEIR 2019	43%			52%	52%
DK	GEIR 2019	45%			50%	50%
DK	MS survey 2019	64%	61%	65%	64%	
EE	GEIR 2019	47%			47%	47%
FI	GEIR 2019	45%			49%	48%
FR	GEIR 2019	42%			47%	47%
DE	GEIR 2019	45%			43%	43%
DE	MS survey 2019	45%	46%	42%	45%	
DE	Own calculation (BAFA 2016, UBA 2016)	43%	44%	43%	43%	
DE	UBA 2016	43%				
DE	Zimmermann 2018		48%			
EL	GEIR 2019	56%			56%	57%
EL	MS survey 2019	60%	60%	60%	53%	
HU	GEIR 2019	43%			36%	36%
IE	GEIR 2019	43%			49%	49%
IT	GEIR 2019	43%			42%	44%
IT	MS survey 2019	46%				
LV	GEIR 2019	44%			43%	47%
LT	GEIR 2019	41%			51%	47%
LU	GEIR 2019	40%			60%	60%
MT	GEIR 2019	47%			54%	54%
NL	GEIR 2019	45%			49%	47%

MS	Source	2014	2015	2016	2017	2018
PL	GEIR 2019	46%			50%	49%
RO	GEIR 2019	46%			49%	49%
PT	GEIR 2019	42%			41%	41%
PT	MS survey 2019	44%	44%	44%	43%	
SI	GEIR 2019	42%			47%	47%
SK	GEIR 2019	45%			48%	48%
ES	GEIR 2019	51%			49%	48%
ES	MS survey 2019	54%	54%	53%	53%	
SE	GEIR 2019	43%			49%	49%
UK	GEIR 2019	43%			49%	49%

Share of collectable waste oil calculated based on dry oil.

7 Waste oil treatment capacities

For the treatment of waste oils different processes can be applied. In general, the following main treatment paths can be distinguished:

- Re-refining to base oils (R9),
- Fuels preparation for, e.g. shipping and energy recovery in the cement, lime and steel industry and in power plants (R1),
- Hazardous waste incineration (D10).

Hazardous waste incinerators and cement kilns and other energy recovery plants are not specifically designed for the treatment of waste oils and can also use other wastes as a feedstock. Therefore, the capacities of these plants are not very meaningful.

Emulsions and their recycling capacities are also not considered here. Emulsions are typically – after water separation – processed into fuels, see Chapter 13.2.3. The emulsions contain additional chemical compounds. Other substances are produced during the application phase, e.g. in metalworking. With an already low proportion of oil in the emulsions, this results in a high proportion of other substances compared to oil. This makes the re-refining of such oil although theoretically feasible more complicated and not practicable.

Therefore, this analysis of waste oil treatment capacities focuses on re-refineries. Inputs to the re-refining process are waste oils of different compositions. According to GEIR (2019), the following waste oils (by LoW codes) are suitable for re-refining:

- 130110* mineral-based non-chlorinated hydraulic oils;
- 130205* mineral-based non-chlorinated engine, gear and lubricating oils;
- 130206* synthetic engine, gear and lubricating oils;
- 130208* other engine, gear and lubricating oils and
- 130307* mineral-based non-chlorinated insulating and heat transmission oils.

Additional LoW codes probably also suitable for re-refining are, depending on declaration and quality control at re-refinery gate:

- 120107* mineral-based machining oils free of halogens (except emulsions and solutions);
- 120110* synthetic machining oils;
- 130111* synthetic hydraulic oils and
- 130113* other hydraulic oils.

Waste oils that cannot be used as a feedstock for the re-refining are: halogenated waste oils, PCB containing waste oils, waste oils originated from or mixed with biodegradable oils, certain industrial oils like metalworking fluids (original as well as emulsions) and certain synthetic oils based, e.g. on silicon oils, polyglycols, phosphoric acid esters.

A quantitative evaluation of waste oil by LoW codes shows that, apart from emulsions, bilge oils and oils from (e.g., oil/water) separation, almost the total amount of waste oil is potentially suitable as input for re-refining.

The output of the re-refining process and the share of the different products are shown in Table 7-1. The share of the products depends on the input (composition of waste oil) and the specific technology of the plant. Today, re-refining plants produce base oils of the API groups I, II and III; see Table 7-2 for details. The main product, the re-refined base oil, makes up for about 60% to 75% by weight compared to the input waste oil.

Re-refined base oils are used as feedstock for gear oils, hydraulic oils, motor, industrial oils and marine oils. The production of the different base oils follows the demand of the lubricant producers. A similar trend as already described for the virgin base oil production (see Chapter 4.2) is also expected for re-refined base oil resulting in a shift towards higher quality base oils (GEIR 2019).

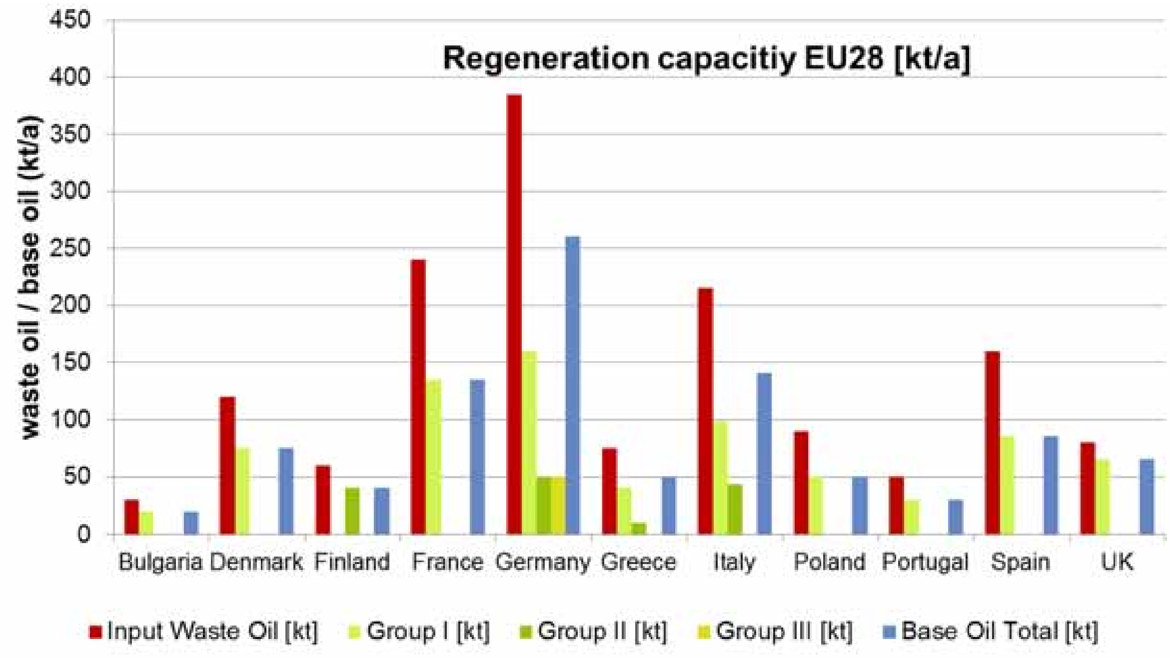
Table 7-1 Typical output of the re-refining process

Product / output	Range %
Base oil(s)	60 - 75 %
Light ends (naphtha)	1 - 3 %
Gas oil	8 - 15 %
Asphalt flux	10 -15 %
Water	3 - 8 %

Source: GEIR 2019

Figure 7-1 provides an overview on the re-refining capacities in the EU-28. More details on the level of individual re-refining plants are provided in Table 7-2. An overview on the geographical location of the re-refineries in the EU is given in Figure 7-2.

Figure 7-1 Regeneration capacity (input waste oil and output base oils groups I to III); EU-28, 1000 t/year, status 2019



Source: compiled by Oeko-Institut, based on Table 7-2

The two figures and the table show that in total 27 re-refineries exist in 11 different Member States[32]. The total capacities of all re-refineries add up to about 1.505 million tonnes of waste oil (input into the re-refineries). The highest capacities, about 0.385 million tonnes of waste oil input or 26% of the total EU-28 capacities, exist in Germany. Germany is followed by France, Italy and Spain, with the four MS together accounting for about 1.0 million tonnes or two thirds of the total capacity.

Figure 7-1 shows that base oil group API I is the main output of the re-refineries in the EU-28. Only one re-refinery in Germany currently produces base oil group III. From Table 7-2 it can be seen that from a capacity of 1.505 million tonnes of waste oil a potential amount of about 0.95 million tonnes of base oil can be produced. This corresponds to an average output of 63% based on the input. From the total base oil output, about 80% is base oil API group I, 15% group II and 5% group III. Considering about 1.05 million tonnes of waste oil going to re-refining in the EU-28 (GEIR 2019), an amount of about 0.67 million tonnes of re-refined base oil can be produced.

In addition to the re-refineries in Table 7-2, a new re-refinery has been announced for Romania: 'Green Oil and Lubes' with a capacity of 73 000 tonnes per year, producing base oil group II, starting in 2019 (Romania 2019).

[32] After a fire in 2017 the re-refinery in Denmark shall re-open in 2020 with a new capacity of about 120 000 tonnes. This capacity is already included in the total EU-28 capacity of 1.505 million tonnes. WOS, based in Hautrage, which was the only company in Belgium to process waste oils, was declared bankrupt at the end of 2015 (Huiles 2017).

Table 7-2 Regeneration capacity waste oil to base oil; EU-28, 1000 t/year, status 2019

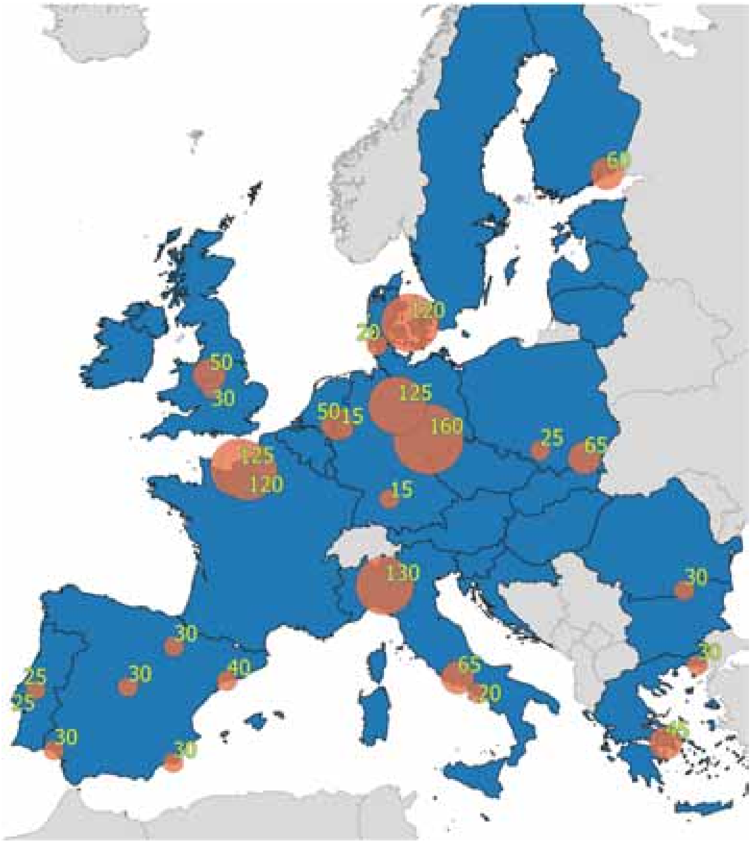
EU-28 Country	Company	Location	Input Waste Oil [kt]	Group I [kt]	Group II [kt]	Group III [kt]	Base Oil Total [kt]	Process	Comment
BG	Lubrica	Ruse	30	20			20		
DK	Avista Oil	Kalundborg	120	75			75	Distillation, similar to Avista oil (see below)	https://www.avista-oil.dk/ destroyed by fire in 2017, new plant (replacement) to open in 2020
FI	STR Tecoil	Hamina	60		40		40		
FR	Eco Huile	Lillebonne	120	60			60	Distillation	http://www.aurea-france.com/en/presentation-groupe-aurea/produits-derives-du-petrole/eco-huile.html
FR	Osilube	Rouen	120	75			75	Wiped-film vacuum distillation process	Osilub 2013, Infineum 2013
total FR			240	135			135		
DE	Puralube	Troeglitz	160		50	50	100	HyLube and HyLube-SAT	
DE	Avista Oil	Dollbergen	125	80			80	Distillation process: Avista Oil	
DE	KS Recycling	Sonsbeck	50	35			35	Distillation	https://www.ks-recycling.de/
DE	Südöl	Eislingen	15	10			10	ENTRA-process	http://www.suedoel.de/
DE	Starke & Sohn	Niebull	20	20			20		Input only transformer oils; products: base oils, transformer oils http://www.starkeundsohn.de/unternehmen.html

EU-28 Country	Company	Location	Input Waste Oil [kt]	Group I [kt]	Group II [kt]	Group III [kt]	Base Oil Total [kt]	Process	Comment
DE	Trafolube	Duisburg	15	15			15		https://www.trafolube.net/de/recycling.html only transformer oil
total DE			385	160			260		
EL	LPC	Attika	45	30			30	Hydro treatment, Distillation	https://www.cyclon-lpc.com/en/
EL	Green Oil	Alexandroupolis	30	10	10		20		
Total EL			75	40	10		50		
IT	Viscolube (now ITELYUM)	Ceccano (Rome)	65	45			45	Distillation process: Viscolube	http://www.itelyum-regeneration.com/it/
IT	Viscolube (now ITELYUM)	Pieve Fissiraga (Milan)	130	43	43		86	Distillation similar to Viscolube above	http://www.itelyum-regeneration.com/it/
IT	R.A.M. Oil	Casalnuovo (NA)	20	10			10	Distillation	http://www.ramoil.it/en/home-eng/
total IT			215	98	43		141		
PL	Jedlicze Oil Refinery	Jedlicze	65	35			35	Distillation	https://www.orlenpoludnie.pl/EN/Pages/default.aspx
PL	Flucar	Kędzierzyn-Koźle	25	15			15		
total PL			90	50			50		
PT	Egeo Oil	Chamusca	25	15			15		
PT	Enviroil	Chamusca	25	15			15		

EU-28 Country	Company	Location	Input Waste Oil [kt]	Group I [kt]	Group II [kt]	Group III [kt]	Base Oil Total [kt]	Process	Comment
total PT			50	30			30		
ES	Cator	Tarragona	40	25			25		http://cator-sa.com/en/
ES	Sertego	Fuenlabrada (Madrid)	30	15			15		Company under a new name: Sertego S. A. https://www.sertego.com/en/
ES	Sertego	Palos de la F. (Huelva)	30	15			15		Company under a new name: Sertego S. A. https://www.sertego.com/en/
ES	Sertego	Alfaro (La Rioja)	30	15			15		Company under a new name: Sertego S. A. https://www.sertego.com/en/
ES	Sertego	Cartagena	30	15			15		
total ES			160	85			85		
UK	Whelan	Stoke on Trent	50	35			35	Distillation	http://www.whelanrefining.co.uk/
UK	EOS	Birmingham	30	30			30		transformer oil
total UK			80	65			65		
Total EU-28			**1505**	**758**	**143**	**50**	**951**		

Source: GEIR 2019 and additional data sources in the table
Transformer oils present a separate mass flow with separate collection and treatment.

Figure 7-2 Geographical location of regeneration capacity waste oil to base oil; EU-28, 1000 t/year, status 2019



Source: Oeko-Institut made with Natural Earth; based on Table 7-2

Using the example of France, the total waste oil treatment capacities including not only re-refining and but also fuel preparation, direct combustion and disposal of waste oils are considered, see Table 7-3. In total, 37 plants provide a capacity for the treatment of about 580 000 tonnes of waste oil in 2012. Two re-refineries exist in France: Osilub with a capacity of about 120 000 tonnes and Eco huile (Aurea) with about 125 000 tonnes. Apart from that, a large number of cement kilns (16 plants) and industrial waste treatment plants (12, assumed to be hazardous waste incinerators) are available for waste oils. The cement kilns provide the second largest capacity for waste oils, 234 000 tonnes or 40%.

Table 7-3 Waste oil treatment capacities in France; year 2012

Treatment	Number	Capacities [t]
Regeneration (re-refining)	2	245 000
Cement kiln	16	234 000
Industrial waste treatment	12	35 930
Combustion plants	3	37 600
Treatment to fuels	4	25 600
Total	**37**	**578 130**

Source: Ademe 2012; Osilub 2013, Auréa 2019

8 Generation and collection of waste oils

Eurostat's waste data, [env_wasgen], from the WStatR are used as a starting point for the evaluation of waste oils. Waste code W013 "Used oils" reported by the MS according to the WStatR quantifies the relevant waste flows per Member State and year. The waste code W013 consists of the two sub-categories, with 33 LoW codes in total (see Table 27-5 in the Annex):

- 01.31 Used motor oils,
- 03.12 "Oils/water emulsions sludges".

At European level, however, no breakdown by LoW code is available. The MS report to Eurostat on W013 "used oils" only.

As far as data is available at MS level by LoW codes (see the example of Germany in Table 8-6), the main share of the waste oils can be identified in the following four different types of waste oils:

- engine, gear and lubricating oils (main LoW code 130205*);
- industrial oils from shaping, physical and mechanical surface treatment (main LoW code 120109*);
- and industrial oils for other uses, e.g. hydraulic, insulating or heat transmission (main LoW code 130307*);
- bilge oils (main LoW code 130403*), *not included in EWC code W013*

W013 "Used oils" include LoW codes 050102* to 050104* and 080319* and 080417*. However, these codes are not foreseen in the waste oil reporting format, see Table 27-2 in the Annex. The main problem related to W013 used oils is that the amounts reported include the water content of waste oils. The water content of different waste oil types can reach from about 5% to about 90% (emulsions). **Thus, the highly aggregated W013 does not allow re-calculating amounts of dry oil, and a comparison with other sources of waste oil data (on dry oil basis) will not be meaningful. Likewise, Eurostat's W013 data does not allow comparison with the consumption quantities of lubricant oils or other quantities of the (waste) oil life cycle analysed in this study.**

Eurostat data on the generation of used oils are generally available for every second year from 2004 to 2016 and are presented in Table 8-1. The generation of waste oils concerns the waste produced in the country and excludes the export and import of waste oils. Furthermore, the generation includes the waste oils produced by waste (pre)treatment activities (e.g. 130506* oil from oil/water separators).

Overall, the reported quantities of waste oils (incl. water) have remained comparatively constant over the last years and vary between 4.0 and 4.5 million tonnes for the EU-28[33]. In 2016, Germany generated 27% of the total EU waste oil, followed by Italy with another 20%. Germany and Italy together with France and the UK account for about 70% of all waste oils. All other MS have a share of 6% (Spain) or less.

[33] High figure of 2006 is caused by a break in time series / inconsistency of Portuguese data.

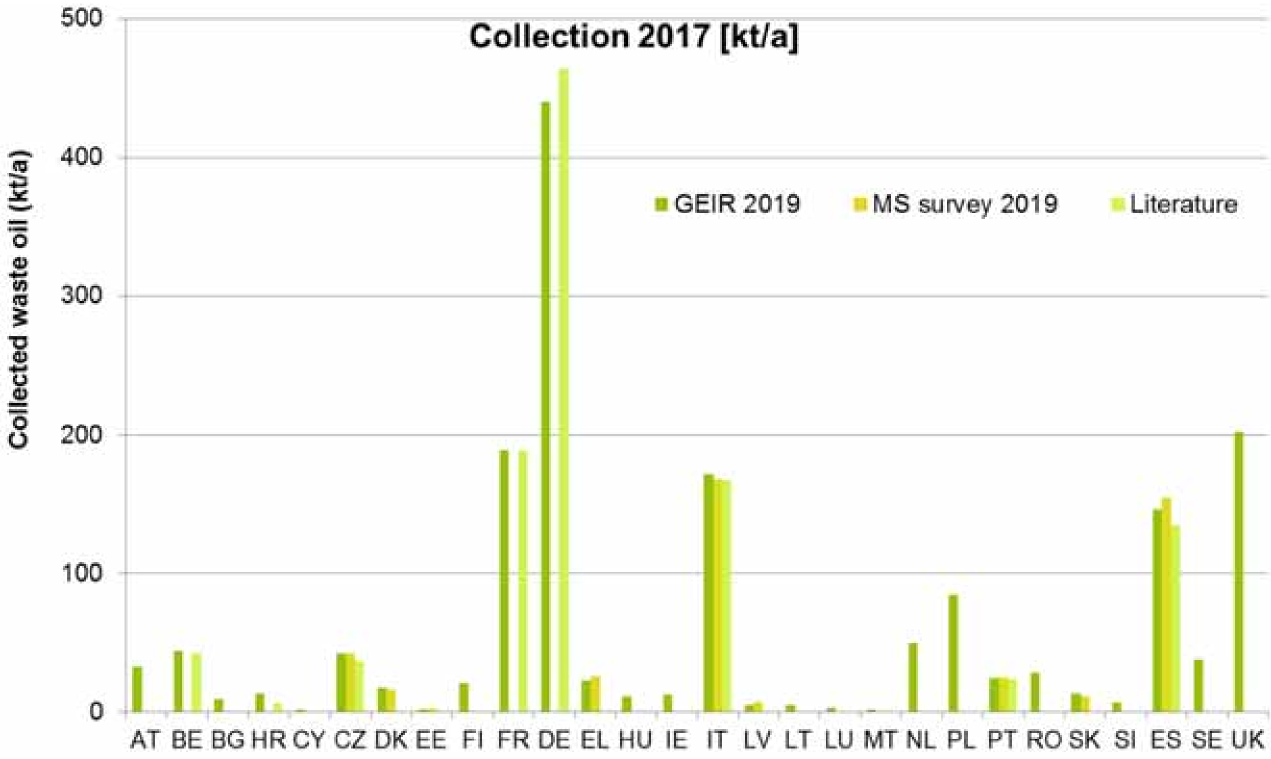
Table 8-1 Generation of used oils in the EU by MS and year; Eurostat [env_wasgen] in tonnes

GEO/TIME	2004	2006	2008	2010	2012	2014	2016
Belgium	185146	180554	188353	110656	172579	98179	121824
Bulgaria	31297	4222	5653	8312	11620	9821	31416
Czechia	60389	55492	66873	56958	57121	66295	84571
Denmark	69792	75046	87581	25025	25639	31733	30791
Germany	1043213	980979	1146455	1042233	1176869	1263222	1152138
Estonia	62594	60462	9808	3134	3153	3469	3436
Ireland	28371	9795	2983	57880	20161	13832	:
Greece	124076	85000	54000	59432	51437	34801	:
Spain	339675	356456	363721	281877	281813	287237	240607
France	536100	495530	604870	627753	624235	480611	511735
Croatia	22891	42558	6499	8712	10482	9904	11995
Italy	542677	641432	658345	554991	642762	779211	853201
Cyprus	25832	4577	5117	3926	4969	6519	5939
Latvia	2137	16236	10295	9763	8281	11582	5686
Lithuania	14611	8745	6055	3972	3329	4372	4802
Luxembourg	9703	8794	8859	7830	13673	17388	17568
Hungary	143747	63465	61305	50034	47295	48490	43275
Malta	2478	2500	2513	68	804	432	286
Netherlands	85926	95732	87075	87617	88157	84422	75494
Austria	80787	73984	71457	70376	35900	36152	40318
Poland	27343	33918	105137	119634	119999	117384	136642
Portugal	87532	2295714	71937	57188	40232	46437	54866
Romania	32935	42321	44645	63392	78027	68592	65778
Slovenia	10907	13496	14519	11219	11295	12432	12326
Slovakia	31000	26673	28967	23259	35024	29041	33496
Finland	48667	89740	29563	46052	30901	57850	37675
Sweden	129307	137349	161576	172350	194067	141274	147184
United Kingdom	463893	583587	588460	434059	510258	438338	459184
EU-28	4240000	6480000	4490000	4000000	4300000	4200000	4230000

: not available
Source: Eurostat [env_wasgen]

As already explained for the consumption of lubricant oils in Chapter 5.1, extensive data was also compiled for the collection of waste oils. This data is mainly based on GEIR questionnaire (2019), MS survey (2019) and additional sources from a desktop research and is presented in full in Table 27-4 in the Annex. A selection of this data is presented in Figure 8-1. Waste oil collection data by MS from different sources are displayed for the year 2017.

Figure 8-1 Collection of waste oils by MS in tonnes (dry oil), year 2017



Source: compiled by Oeko-Institut, based on Table 27-4 in the Annex

Germany collected by far the highest amount of waste oils, about 440 000 tonnes or 27% of the total waste oils collected in the EU-28 in 2017. The UK, about 200 000 tonnes, France, about 190 000 tonnes, Italy, about 170 000 tonnes, and Spain, about 150 000 tonnes, are the MS with the next highest amounts of collected waste oil. The five MS together collected more than two thirds of the overall collected waste oil in the EU-28. In total, about 1.64 million tonnes of waste oils were collected in the EU-28 in 2017[34].

From an overall point of view, the deviations of the quantities between the individual data sources are small. In the case of Spain, for example, the figure of Sigaus (2017) is 8% or about 11 500 tonnes smaller than the quantity collected according to GEIR (2019), and the figure from MS survey 2019 is about 9 100 tonnes or 6% higher than the GEIR figure. Where the differences originate cannot be explained sufficiently as data on the level of individual LoW codes are only available in exceptional cases. Generally, GEIR data should not include emulsions, while data from the MS survey and the other data sources should include emulsions, respectively the dry oil content of the

[34] GEIR is the only data source which covers all MS. Therefore, shares and EU totals are based on GEIR data.

emulsions[35]. However, in many cases GEIR data for a given MS is higher than data from other sources. Recalculation into dry oil is a principle source of deviation. Obvious differences occur for Croatia and Latvia. However, these differences in collected waste oils are not relevant for the EU totals.

The total amounts of collected waste oils in the EU-28 are similar in the years 2014, 2017 and 2018. The quantities collected vary between about 1.68 million tonnes (2014) and about 1.64 million tonnes (2017 and 2018) and no clear trend is visible. An evaluation at MS level reveals that the collection quantities in the years from 2014 to 2018 remain roughly at the same level. For some MS, the collection quantities are increasing and for others decreasing.

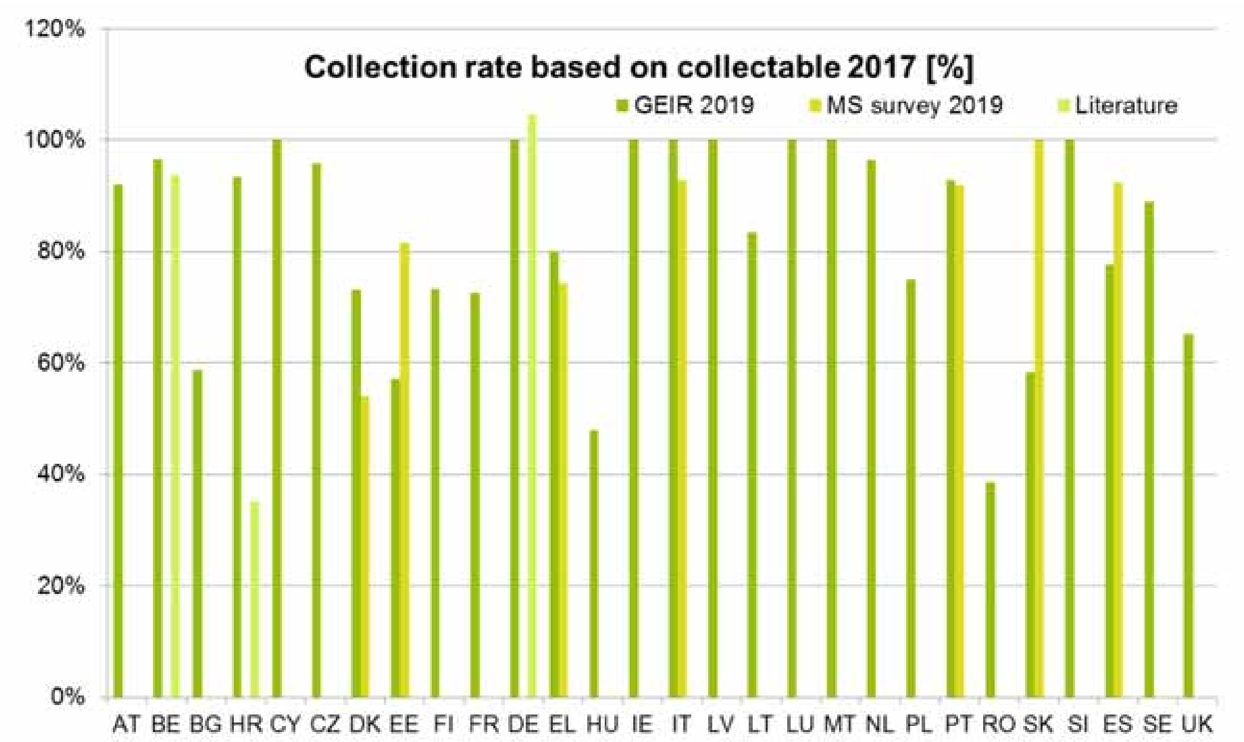
Figure 8-2 presents waste oil collection rates by MS for the year 2017. The collection rates represent the share of the collectable waste oil being actually collected. Most MS collected between about 60% and 100% of the collectable amount of waste oil. Only for Hungary and Romania did collection rates below 50% result. More than a dozen MS achieved collection rates of between 90% and 100%[36]. Collection rates from the different data sources vary considerably for several MS and in particular for Croatia and Slovakia[37]. Little data is available from the literature as these sources do not normally consider collectable amounts of waste oil. However, caution is needed when comparing the collection rates between MS. As already explained in Chapter 6, it is difficult to assess the share of collectable waste oil, as potential inconsistencies or inaccuracies of the overall return rates might occur for different reasons (for example the inclusion of process lubricants, other oils not producing waste oils, greases or emulsions or use of one (or more) unspecific default values for the calculation of the return rate).

[35] Emulsions account for about 2% in Belgium and about 14% in Germany of the total collected waste oil (based on dry oil).

[36] For Germany a collection rate above 100% results due to inconsistencies between the theoretically derived overall return rate (collectable waste oil) and the statistically derived amounts of actually collected waste oil; see Chapter 6.3 for more details on the German figure.

[37] No explanation is available for Croatia. In the case of Slovakia, no consumption figure is given in the MS survey and the submitted amount of collectable waste oil is identical with the amount collected.

Figure 8-2 Collection rate of waste oil (%; based on collectable waste oil) by MS, year 2017



Sources: GEIR 2019, MS survey 2019 and literature, see Table 27-4

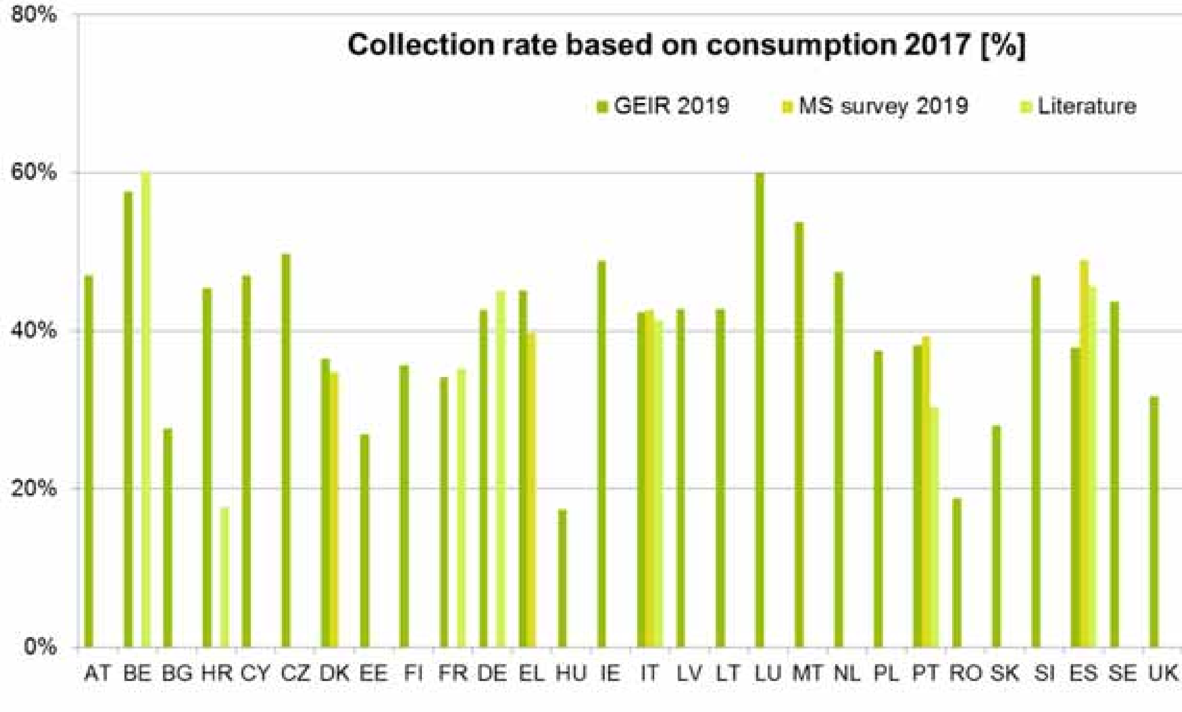
In contrast to the collection rate in Figure 8-2, the collection rate in Figure 8-3 is not based on the collectable amount of waste oil but rather on the consumption of lubricant oil. As a result, the collection rates in Figure 8-3 must be considerably lower. **The collection rates as the share of the collected waste oil (dry oil) of the lubricant oil PoM is evaluated as an alternative method for assessing the collection activities in Member States.**

According to this approach, two MS, Belgium and Luxembourg, achieve collection rates of up to 60%. Collection rates of more than a dozen MS are between 40% and 50% and another nine MS have collection rates between 25% and 40%. As in the case of the collection rate based on collectable waste oil, Hungary and Romania display the lowest collection rates, less than 20%. Many MS for which highest collection rates based on collectable waste oil result also have high collection rates based on consumption (e.g. Austria, Cyprus, Czech Republic, etc.). For other MS such as Portugal or the Netherlands some smaller differences occur in the ranking.

A collection rate based on the amount PoM (consumption) has the advantage of better data quality, as data inconsistencies and methodological problems related to the calculation of collectable waste oil are ruled out. At the same time, however, this has the disadvantage that unavoidable losses, which vary from MS to MS, are not addressed as they are not accounted for separately.

A direct comparison of the two methods of the calculation of the collection rates in Figure 17-1 in Chapter 17 shows an overall satisfying degree of similarity in the order of the MS based on collection rates. Differences occur most of all for the MS with the highest collection rates.

Figure 8-3 Collection rate of waste oil (%; based on consumption) by MS, year 2017



Sources: GEIR 2019, MS survey 2019 and literature, see Table 27-4

A comparison of the amounts of collected waste oil with the treatment options and capacities and with the amounts of lubricants oils placed on the market will follow in Chapters 10 and 12.

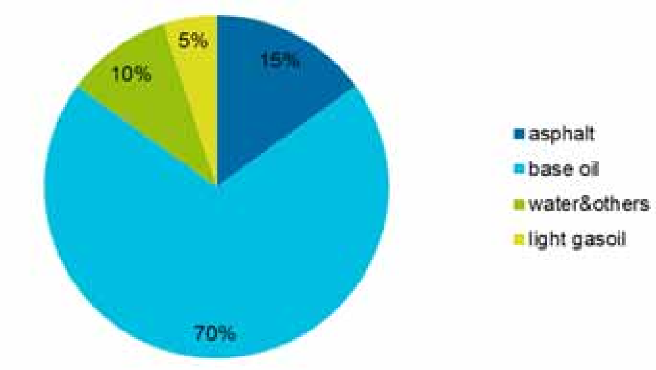
8.1 Water content of waste oils

As already described above, quantities of waste oils differ widely depending on whether the water content is considered or not[38]. When considering the water content of waste oils it needs to be differentiated between the actual waste oil and emulsions.

Figure 8-4 shows a common composition of waste oil. The water content accounts for up to around 10% of the waste oil. About 70% base oil may be regenerated from the total waste oil.

[38] Wastes oils excluding water content are called "dry oils" in this study.

Figure 8-4 Composition of waste oil



Source: Lube 2013

A Belgium report on waste oils provides information on the content of waste oils and emulsions (Valorlub 2016). Based on this report, the water content of waste oils is about 5% (and additional 1% of sediments) and the water content of emulsions is about 95%.

From waste oils collected in Spain (Sigaus 2017) and the amount of waste oils remaining after separation of water and sediments an average water content of about 21% (incl. sediments, no differentiation between actual wastes oils and emulsions) can be calculated. For Italy (Conou 2017) and Portugal (SIGOU 2018), a water content of collected waste oil of about 10% is calculated for both countries.

More detailed information of water contents on the level of LoW codes is provided in a German study for the German Federal Environmental Agency (UBA 2016). Chemical analysis of specific waste oils (according to LoW codes) can be viewed online in a German hazardous waste portal (Abanda 2018). Based on these two German sources on the level of individual LoW codes water contents of waste oils in Table 8-2 were developed.

Table 8-2 Water content of waste oils and emulsions by LoW code

LoW codes		Water content %
130204*	mineral-based chlorinated engine, gear and lubricating oils	7,5
130205*	mineral-based non-chlorinated engine, gear and lubricating oils	9,5
130206*	synthetic engine, gear and lubricating oils	9,5
130207*	readily biodegradable engine, gear and lubricating oils	9,5
130208*	other engine, gear and lubricating oils	11,9
120106*	mineral-based machining oils containing halogens (except emulsions and solutions)	36,4
120107*	mineral-based machining oils free of halogens (except emulsions and solutions)	36,4
120108*	machining emulsions and solutions containing halogens	90,4
120109*	machining emulsions and solutions free of halogens	90,4
120110*	synthetic machining oils	36,4
120119*	readily biodegradable machining oil	36,4

LoW codes		Water content %
130101*	hydraulic oils, containing PCB	3.9
130104*	chlorinated emulsions	90.4
130105*	non-chlorinated emulsions	90.4
130109*	mineral-based chlorinated hydraulic oils	3.9
130110*	mineral based non-chlorinated hydraulic oils	3.9
130111*	synthetic hydraulic oils	3.9
130112*	readily biodegradable hydraulic oils	5.5
130113*	other hydraulic oils	3.9
130301*	insulating or heat transmission oils containing PCBs	1.3
130306*	mineral-based chlorinated insulating and heat transmission oils other than those mentioned in 13 03 01	1.3
130307*	mineral-based non-chlorinated insulating and heat transmission oils	1.3
130308*	synthetic insulating and heat transmission oils	1.3
130309*	readily biodegradable insulating and heat transmission oils	1.3
130310*	other insulating and heat transmission oils	1.3
130802*	other emulsions	90.4
130401*	bilge oils from inland navigation	90.0
130402*	bilge oils from jetty sewers	95.0
130403*	bilge oils from other navigation	80.0
130506*	oil from oil/water separators	51.8
190207*	oil and concentrates from separation	23.4

Source: UBA 2016, Abanda 2018; calculations Oeko-Institut

8.2 Individual MS data on collected waste oils

In this section a more detailed analysis of waste oil collection for the examples of Belgium, Spain, Italy and Germany was performed.

Belgium

Data representing the situation in Belgium (years 2012 to 2017 in Table 8-3) shows that annually about 68 000 to 73 000 tonnes of lubricants are placed on the market and about 40 000 to 43 000 tonnes of waste oils are collected (Belgium 2017). Amounts of lubricants consumed and waste oil collected show comparably small differences from 2012 to 2017 with no clear trend visible. Consequently, the collection rates based on the consumption varies only between 56% and 63% (for comparison, the return rate is about 72%). Emulsions or respectively their calculated dry oil content (about 1000 tonnes of dry oil) account only for about 2% to 3% of the total collected waste oils. The water content of the total collected waste oils on average accounts for about 29% (for comparison Spain 21%).

The amount of collected waste oil for the years 2014 and 2017 according to GEIR figures is very similar to the figures described above. Significant differences, however, occur for the consumption and in particular for the year 2014 (110 000 tonnes compared to only about 69 000 tonnes). Some of the differences might be explained by the fact that process oils, greases and other lubricants not producing waste oil are probably not included in the figures from (Belgium 2017). However, the overall difference remains unknown.

Table 8-3 (Waste) oil data for Belgium; years 2012 to 2017; amounts in tonnes, rates in %

Source	Content	2012	2013	2014	2015	2016	2017
Belgium 2017	Consumption	73 261	68 320	69 074	71 415	72 326	70 314
Belgium 2017; own calculation	Collected emulsion dry oil	863	839	964	989	1 123	1 108
Belgium 2017; own calculation	Collected waste oils (dry)	41 737	41 403	42 567	42 541	39 507	41 175
Belgium 2017; own calculation	Total collected (dry)	42 600	42 242	43 531	43 530	40 629	42 283
Own calculation	collection rate (consumption)	58%	62%	63%	61%	56%	60%
GEIR 2019	Consumption			110 000			77 000
GEIR 2019	Total collected (dry)			45 000			44 400
Own calculation	collection rate (consumption)			41%			58%

Source: see Table 27-4 in the Annex

Spain

Data representing the situation in Spain (years 2012 to 2017 in Table 8-4) shows that annually between 270 000 to 390 000 tonnes of lubricants were placed on the market, depending on the data source and the year. GEIR data, about 390 000 tonnes in 2017, is considerably higher than the figures from Sigaus and the MS survey. Differences might be explained by the fact that GEIR data includes process oils and greases while the other data sources do not.

Amounts of collected waste oil range from about 126 000 tonnes to about 155 000 tonnes. Data differences between the three sources are less significant for waste oils. Data from Sigaus is displayed on a timeline from the year 2012 to 2017. The amounts of yearly collected waste oil vary between about 121 000 tonnes and 135 000 tonnes and do not show a clear trend.

The collection rates based on the consumption vary between 38% and 52%. For comparison, the return rate varies between 48% and 53%. The collection rate calculated from GEIR data is only 38% due to process oils and greases being included. Considering only collectable waste oils, collection rates between 74% and 96% are achieved.

Table 8-4 (Waste) oil data for Spain; years 2012 to 2017; amounts in tonnes, rates in %

Source		2012	2013	2014	2015	2016	2017
SIGAUS 2017	consumption			278342	291670	298847	295143
SIGAUS 2017	Waste oil collected (incl. water)	163944	160319	159425	152630	154206	170070
SIGAUS 2017	Water, Sediments	34281	33523	33336	31915	32245	35562
SIGAUS 2017, own calculation	Collected waste oils (dry)	129663	126796	126089	120715	121961	134508
Own calculation	Collection rate (consumption)			45%	41%	41%	46%
GEIR 2019	consumption			331200			385480
GEIR 2019	collectable waste oil			169200			188000
GEIR 2019	Return rate			51%			49%
GEIR 2019	Total collected (dry)			126900			146052
Own calculation	Collection rate (consumption)			38%			38%
GEIR 2019, own calculation	Collection rate (collectable)			75%			78%
MS survey 2019	consumption			271526	284194	311518	316872
MS survey 2019	collectable waste oil			146058	153059	165697	168040
MS survey 2019	Return rate			54%	54%	53%	53%
MS survey 2019	Total collected (dry)			140086	134098	137716	155117
Own calculation	Collection rate (consumption)			52%	47%	44%	49%
MS survey 2019, own calculation	Collection rate (collectable)			96%	88%	83%	92%

Source: see Table 27-4 in the Annex

Italy

Table 8-5 presents data for Italy for the year 2017 from three different data sources. GEIR and CONOU data is almost identical. Differences in the amount of waste oil collected might be due to different water content which was assumed for the calculation of dry oil. Differences to the figures from the MS survey mainly occur for the lubricant consumption. The consumption figures (MS survey 2019) are displayed once excl. process oils, greases and other oils not for lubricating (left) and once incl.

these oils (right). GEIR figures should include process oils, greases and other oils not for lubricating and thus should be comparable to the MS survey figures in the right-hand column. Some of the remaining differences might be explained by missing marine oils in the case of GEIR.

Lubricant oils in the range of about 390 000 tonnes to 430 000 tonnes were PoM in 2017. About 41% to 46% - depending on the data source - of this amount are considered to be collectable. 183 000 tonnes waste oil or respectively between 168 000 tonnes and 172 000 tonnes dry oil were actually collected. Thus, a collection rate of about 38% to 43% results based on the consumption. When considering the collectable amount of wastes oil the collection rate is between about 93% and 100%.

Table 8-5 (Waste) oil data for Italy; year 2017

Italy 2017	Conou 2017	GEIR 2019	MS survey 2019; excl. process oils etc.	MS survey 2019; incl. process oils etc.
Consumption [t]	406 000	406 000	393 400	439 600
Collectable Waste Oil (incl. water) [t]		183 000		
Collectable Waste Oil (dry) [t]		172 020	181 000	181 000
Collectable Waste Oil (dry) based on Consumption [%]		42.4%	46.0%	41.2%
Collected Waste Oil (incl. water) [t]	182 700	183 000	183 000	183 000
Collected Waste Oil (dry) [t]	167 725	172 020	168 000	168 000
Collection rate based on consumption [%]	41.3%	42.4%	42.7%	38.2%
Collection rate based on collectable [%]		100%	92.8%	92.8%

Source: see Table 27-4 in the Annex

Germany

Table 8-6 provides data on waste oils ('Total' incl. water) from the German Statistical Office (Destatis 2016). Dry oils are calculated by Oeko-Institut based on the water content in Table 8-2.

The sum A+B in Table 8-6 is expected to have a similar scope of LoW codes as the Eurostat data in Table 8-1 and the GEIR data[39] in Table 27-4. A+B ('Total' incl. water) in Table 8-6 accounts for about 1.16 million tonnes (2014) and 1.11 million tonnes (2016). Eurostat data is similar, 1.26 tonnes (2014) and 1.15 tonnes (2016). A+B ('Dry oil') in Table 8-6 account for about 484 000 tonnes (2014) and 464 000 tonnes (2017) while GEIR data in Table 27-4 is about 462 000 tonnes (2014) and

[39] However, GEIR data excludes emulsions.

440 000 tonnes (2017). Differences between GEIR data and the data in Table 8-6 might partially be explained by missing emulsions in GEIR data.

Table 8-6 Collected waste oils in Germany by LoW code and year; 1000 tonnes; Total incl. water; Dry excl. water

LoW codes	Total 2014	Total 2015	Total 2016	Total 2017	Dry 2014	Dry 2015	Dry 2016	Dry 2017
A+B	**1 157**	**1 149**	**1 117**	**1 109**	**484**	**485**	**468**	**464**
A	**425**	**430**	**413**	**411**	**384**	**388**	**374**	**371**
130204*	1	1	1	1	1	1	1	1
130205*	404	409	393	390	365	370	356	352
130206*	1	1	1	1	0	0	1	0
130207*	0	0	0	0	0	0	0	0
130208*	20	19	19	20	17	17	16	17
B	**732**	**719**	**703**	**698**	**100**	**97**	**95**	**93**
120106*	0	0	0	0	0	0	0	0
120107*	30	28	26	25	19	17	17	16
120108*	1	1	1	2	0	0	0	0
120109*	648	639	625	619	62	61	60	59
120110*	1	1	1	1	1	1	1	0
120119*	0	0	0	0	0	0	0	0
130101*	0	0	0	0	0	0	0	0
130104*	0	0	0	0	0	0	0	0
130105*	10	10	9	9	1	1	1	1
130109*	0	0	0	0	0	0	0	0
130110*	2	2	2	2	2	2	2	2
130111*	0	0	0	0	0	0	0	0
130112*	0	0	0	0	0	0	0	0
130113*	0	0	0	0	0	0	0	0
130301*	1	1	1	1	1	1	1	1
130306*	0	0	0	0	0	0	0	0
130307*	10	11	10	10	10	10	10	10
130308*	1	1	1	1	1	1	1	1
130309*	0	0	0	0	0	0	0	0
130310*	0	0	0	0	0	0	0	0
130802*	28	27	27	29	3	3	3	3
*190207**	*69*	*68*	*99*	*95*	*53*	*52*	*75*	*73*
Bilge oils	*109*	*121*	*136*	*133*	*21*	*24*	*27*	*26*
Others	*6*	*6*	*7*	*5*	*4*	*3*	*4*	*3*

Source: Destatis 2016, calculation Oeko-Institut, figures without decimal places
A: Engine oils, including motor oils and gear oils; 130204* to 130208*
B: Industrial oils, including machining oils and emulsions, hydraulic oils, oils for turbines, transformer oils, insulating and heat transmission oils; 120106* to 130802*

9 Imports and exports of waste oils

Data on imports and exports of waste oils are available from Eurostat's database on the Transboundary Shipments of Waste (WShipR[40]).

Figure 9-1 presents as an overview the difference of import minus export of waste oils (dry oil excl. water[41]; to and from EU and non-EU countries) by MS for the years 2014 to 2016. In addition, Table 27-6 lists in the Annex II import and export data (to and from EU and non-EU countries) of waste oils of all MS. The most detailed import and export data by LoW code and treatment category (D1 to D11 and R1 to R12) were analysed and are presented exemplarily in Table 27-7 in the Annex. Overall, between about 160 000 tonnes and 300 000 tonnes of waste oils (dry oil) were exported annually in total by all MS in the years 2011 to 2016[40]. In 2014, all MS together exported almost 300 000 tonnes waste oils (dry oils). This equals a share of about 18% compared to the amount collected by all MS in 2014. In the same year, about 320 000 tonnes were imported by all MS[40,42].

According to GEIR there is no evidence that waste oil is exported to non-EU countries. Imports of waste oil from non-EU countries into the EU, however, take place and range from about 20 000 to 30 000 tonnes per year. (GEIR 2019)

Figure 9-1 shows that Germany is with more than 120 000 tonnes by far the largest waste oil net importer of the EU. All other net imports amount to about 20 000 tonnes or less of waste oil per year. Five MS (BE, FR, NL, SE and UK) are the most relevant net exporters with more than 20 000 tonnes. The share of net imports / net exports of the total waste oil collected varies significantly between MS. While for example Belgium exports about the total amount of waste oil collected (year 2014), Germany's net imports account for about one fourth of the amount collected in Germany (2014).

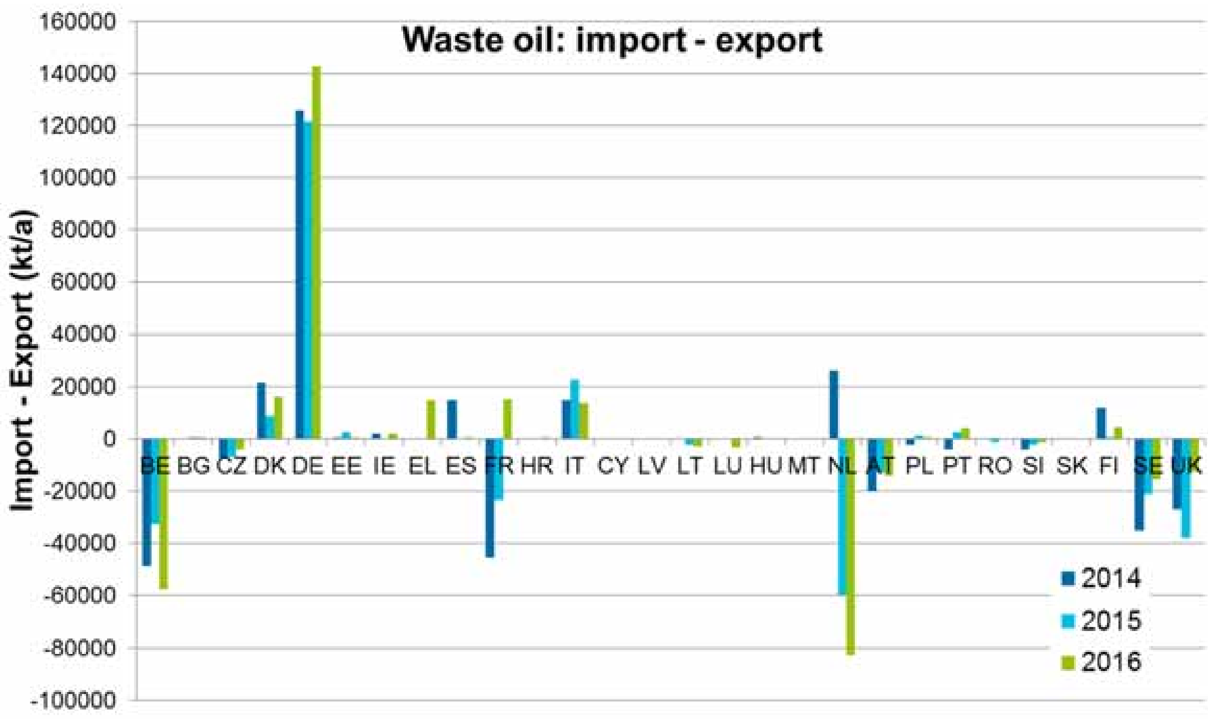
Furthermore, Figure 9-1 shows some noticeable differences for France and Netherlands: the two MS change their respective trends between 2014 and 2016, with the FR switching from being a net exporter to a net importer, and NL doing the opposite.

[40] WShipR allows transboundary shipments of hazardous wastes only to OECD countries. In the case of waste oils, the vast majority is intra-EU shipments. Thus, waste oils are mostly shipped from a MS to another.

[41] Calculated by Oeko-Institut based on import/export data incl. water.

[42] The remaining difference between imports and exports might be explained by imports from non-EU countries or statistical inconsistencies.

Figure 9-1 Waste oil (dry oil) import minus export by MS; t/a, years 2014 to 2016



Source: Eurostat, Transboundary Shipments of Waste (WShipR); imports: incl. imports from MS and non-EU countries; exports: incl. exports to MS and non-EU countries; waste oils excl. water (calculated by Oeko-Institut)

The analysis of the import / export data allows a comparison and a consistency check with, e.g. collected waste oils, re-refining capacities and input into re-refining. Therefore, data from previous sections are compared with import / export data in Table 9-1 for the year 2014. In the following, a short summary of the analysis is provided for selected MS (mainly MS with re-refineries). The assessment of the results must take into account general data inaccuracy (e.g. incl. or not the water content[43]), the use of different data sources and potential statistical inconsistencies.

France: The French data (2014) shows that about 120 000 tonnes of waste oil from in total about 200 000 tonnes collected go into re-refining in France while at the same time roughly 40 000 tonnes are exported for re-refining. As can be seen in Figure 9-1 France changes from a net exporter in 2014 to a net importer in 2016. It seems, that the second re-refiner (Osilub, which added about half of the total re-refining capacity) commenced operations during the time period under consideration.

The Netherlands: As already described above, the Netherlands changed from a net importer to a net exporter. This in turn can be explained by the fact that the sole re-refiner went bankrupt in 2015.

[43] GEIR 2019 data incl. 6% water; in TSW data water is deducted (calculated by Oeko-Institut based on water content in Table 8-2); R9 considers additionally "other reuses" while GEIR 2019 considers only re-refining.

Denmark: Denmark had in 2014 re-refining capacities of about 40 000 tonnes of waste oil (after a fire in 2017 the re-refinery shall re-open in 2020 with a new capacity of about 120 000 tonnes). The total waste oil collected (about 20 000 tonnes) and additional imports about used up the capacities in 2014.

Germany: Only about half of the amount collected went into re-refining in 2014 (about 240 000 tonnes of waste oil). An additional amount of about 110 000 tonnes of waste oil were imported (net imports) for re-refining. These amounts compare to Germany's re-refining capacities of about 385 000 tonnes (2019).

Greece: All collected waste oils went into re-refining (about 24 000 tonnes) in 2014. In 2016 an additional about 15 000 tonnes of waste oil were imported (net import) for re-refining (2014 either no data or no import/export). Re-refining capacities increased in Greece to about 75 000 tonnes of waste oil today (nameplate, therefrom only about 45 000 tonnes are available).

Spain: About 90 000 tonnes waste oil of about 135 000 tonnes collected went into re-refining. About 10 000 tonnes of additional waste oil were imported in 2014 (net import), compared to about 190 000 tonnes of re-refining capacities in 2019.

Italy: About 165 000 tonnes waste oil of about 180 000 tonnes collected went into re-refining. Additionally, about 15 000 tonnes of waste oil were imported in 2014 (net import); compared to about 215 000 tonnes of re-refining capacities in 2019.

Poland: Only about one third (about 32 000 tonnes of waste oil) of the amount collected went into re-refining in 2014. About half of the collected waste oil was treated to fuel and the remaining share was exported for re-refining. In addition, low net exports of waste oil took place in 2014. These amounts compare to Poland's re-refining capacities of about 90 000 tonnes (2019). This data indicates that the re-refining capacities might not be used up in Poland. This might be explained by economic reasons: re-refining cannot compete with the use/treatment of waste oil to fuel.

Finland: About 20 000 tonnes waste oil of about 22 000 tonnes collected went into re-refining. Additionally, about 5 000 tonnes of waste oil were imported for re-refining in 2014 (net import); compared to about 60 000 tonnes of re-refining capacities. This data indicates that the re-refining capacities might not be used up in Finland. One reason for this is the financial conditions; costs for re-refining are too high.

UK: About 35 000 of a total of about 250 000 tonnes of waste oil collected went into re-refining. However, about 20 000 tonnes of waste oil were exported for re-refining in 2014 (net export), compared to about 80 000 tonnes of re-refining capacities (2019).

Portugal: in 2014 about half of the collected waste oil is exported for re-refining; however, data from GEIR and the MS survey differ. Depending on the data source, 0% is re-refined in Portugal (GEIR 2019) or 22% is ref-refined in Portugal (MS Survey 2019). These shares increased significantly and in the subsequent years between 67% and 74% (about 15 000 tonnes to 20 000 tonnes of waste oil) are re-refined in Portugal. The amount of waste oil being exported for re-refining is decreasing and amounts for about 4% in 2017 (MS Survey 2019). In Portugal only one of two re-refineries is operational. Therefore, it is assumed that the remaining share of about one fourth of the collected waste oil had to be treated differently ('Other recycling' (SIGOU 2018) or 'Treatment to fuels' (GEIR 2019)).

MS without their own re-refining capacities export waste oils mainly for re-refining. However, the share of the collected waste oil which is exported for re-refining differs in these MS. Austria for example exports more than two thirds of its collected waste oil for re-refining while, e.g. the Czech Republic exports only about one fourth of the amount collected.

Overall, MS with their own refineries import waste oils (net import) presumably to make better use of their re-refining capacities.

Some data, see above, indicates that re-refining capacities might not be used up in the EU. About 1.505 million tonnes of re-refining capacities in the EU-28 in 2019 compare to about 1.05 million tonnes of waste oil going to re-refining in 2018 (GEIR 2019).

However, operational standstill periods and a time-related development of the capacities in recent years need to be considered and thus make an assessment difficult (e.g. in the 1.505 million tonnes the re-refinery in Denmark which shall only re-open in 2020 is already included).

Table 9-1 Comparison of imports and exports of waste oils with collected, capacities, etc.; tonnes/a, year 2014

Tonnes/a	Collected incl. water (GEIR 2019)	Re-refining capacity (GEIR 2019)	Re-refining (GEIR 2019)	Export re-refining (GEIR 2019)	R9 Im-Ex (net) WShipR	Total Im-Ex (net) WShipR
BE	45000		0	-38000	-19364	-48713
BG	8000	30000	7000	0	-282	-282
CZ	40000		0	-10000	-7355	-7355
DK	20000	120000	20000	0	21518	21518
DE	462000	385000	224000	-11000	113680	125831
EE	1500		0	0	-441	518
IE	14000		0	0	2337	1707
EL	24000	75000	24000	0	0	-5
ES	135000	160000	90000	0	9428	14740
FR	211000	240000	118000	-38000	-54968	-45623
HR	14000		0	0	0	0
IT	180000	215000	165000	0	15331	14590
CY	3000		0	0	0	0
LV	6000		0	0	-163	-163
LT	5000		0	-4000	0	-21
LU	3000		0	-2000	0	0
HU	12000		0	0	552	191
MT	2000		0	0	0	0
NL	48000		0	-30000	24023	26277
AT	33000		0	-23000	-22518	-20091
PL	90000	90000	32000	-8000	-2347	-2322
PT	25000	50000	0	-15000	-4342	-4342
RO	25000		0	0	0	-11

Tonnes/a	Collected incl. water (GEIR 2019)	Re-refining capacity (GEIR 2019)	Re-refining (GEIR 2019)	Export re-refining (GEIR 2019)	R9 Im-Ex (net) WShipR	Total Im-Ex (net) WShipR
SI	7000		0	0	-2265	-4186
SK	14000		0	0	0	-251
FI	22000	60000	20000	0	5365	11761
SE	40000		0	-20000	-24314	-35210
UK	250000	80000	35000	-20000	-19115	-26956

Exports are shown with a negative sign in this table
Re-refining capacities status 2019
WShipR = Transboundary Shipment of Waste; R9: Used oil re-refining or other reuses of previously used oil
GEIR 2019: waste oil incl. 6% water

10 Treatment of waste oils

Data on the different treatment processes of waste oils is available from Eurostat, GEIR (GEIR 2019) and individual Member States (MS survey 2019 and other sources).

Eurostat data on treatment flows are for several reasons not comparable with Eurostat data on waste oil generation in Table 8-1. The generation of waste oils concerns the waste produced in the country, while the treatment also takes into account export and import of waste oils. Furthermore, generation includes the waste oils produced by waste (pre)treatment activities (e.g. LoW code 130506* oil from oil/water separators), whereas treatment only includes the final treatment. Finally, differences can also occur due to the different water content of the waste oils.

Due to missing data of several MS, only GEIR (2019) and Eurostat data allow an evaluation of waste oil treatment on the EU-28 level.

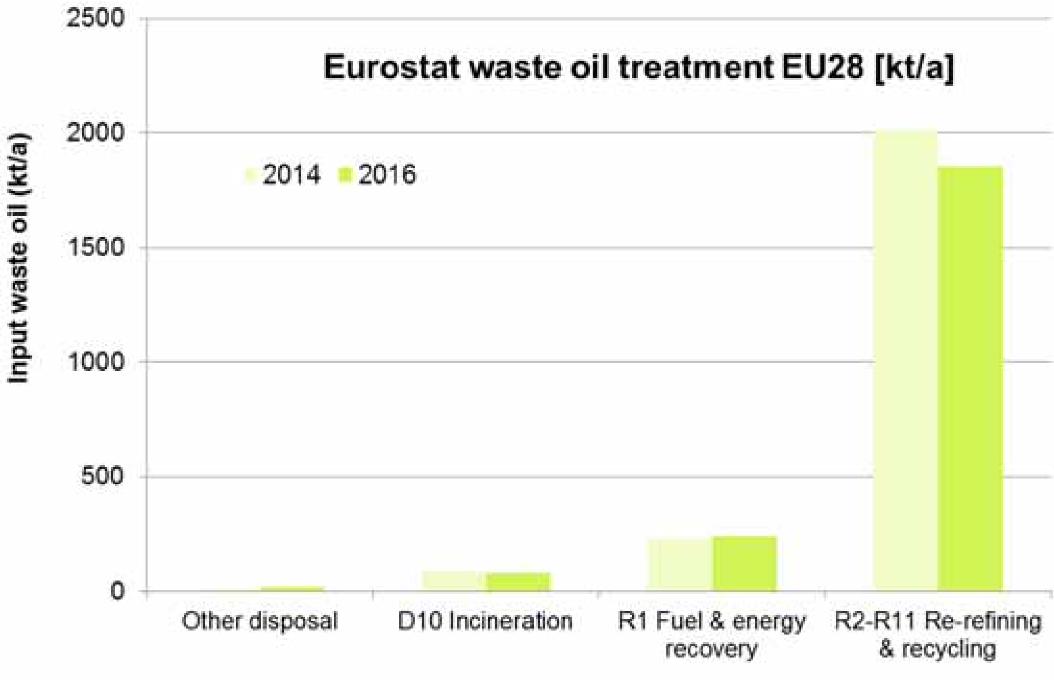
Figure 10-1 provides an overview on the treatment of waste oils in the EU-28. The waste oil inputs into the different recycling and disposal processes[44] for the years 2014 and 2016 are presented. In total, about 2.34 million tonnes of waste oils were treated in the EU-28 in 2014 and about 2.19 million tonnes in 2016. By far the largest amount, about 2.0 million tonnes or 86% (2014; compared to 84% in 2016) went into re-refining and other recycling of waste oil[45]. 'R1 Use as a fuel (other than in direct incineration) or other means to generate energy'[46] accounts for about 10% (2014 and 11% in 2016) of the total waste oil treatment. The remaining 4% to 5% of the total waste oil is disposed of almost exclusively in hazardous waste incineration plants (D10). Detailed Eurostat data on waste oil treatment by MS are provided in Table 27-8 in the Annex.

[44] Please see EWC-STAT for the description of the recycling and disposal processes (R1 to R13 and D1 to D13).

[45] Eurostat data only provides data for R2-R11 in total; assumption: only 'R9 Used oil re-refining or other reuses of previously used oil' is relevant.

[46] Use as a fuel in shipping and energy recovery in, e.g. the cement, lime and steel industry and in power plants.

Figure 10-1 Waste oil treatment total EU-28, input in kt/a, years 2014, 2016



Source: Eurostat [env_wastrt]

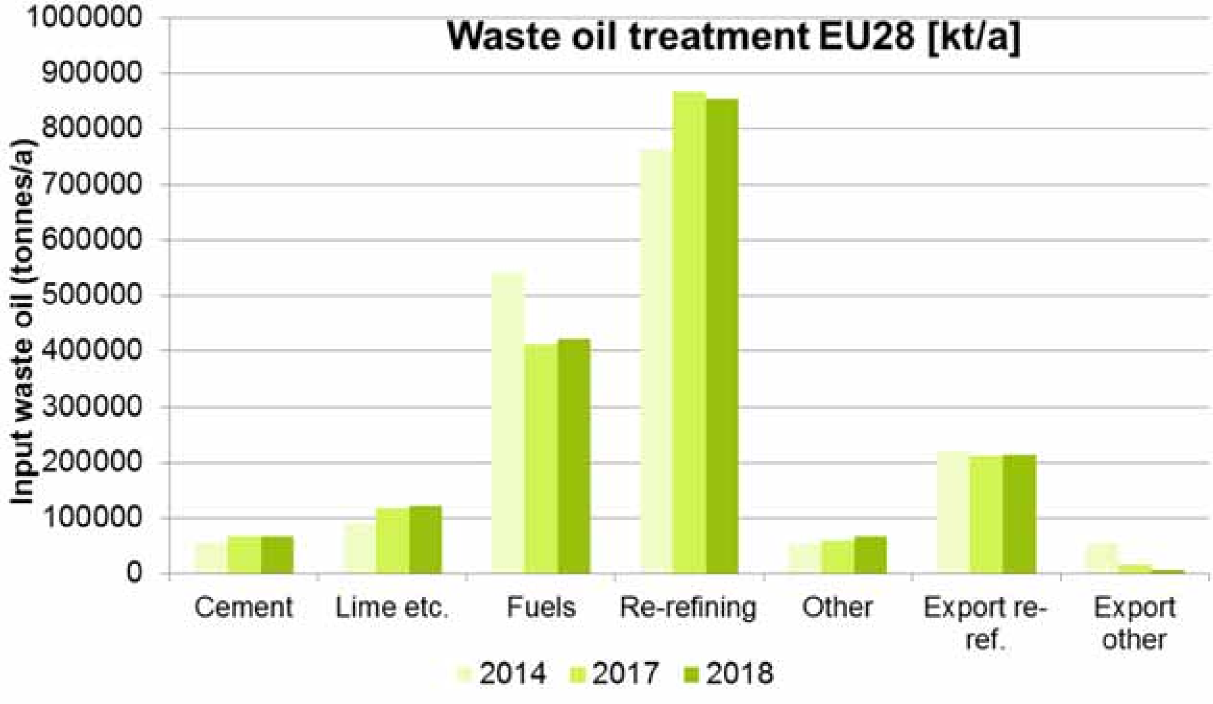
Figure 10-2 shows waste oil treatment flows of the EU-28 based on GEIR (2019) for the years 2014, 2017 and 2018. GEIR data covers the treatment of all waste oils collected in the EU-28 (excl. emulsions; waste oil water content of about 6%). Assuming that exports (and imports) to (and from) non-EU countries are negligible, the data represents the total amount treated in the EU-28. In total, about 1.78 million tonnes of waste oil were treated in 2014 and slightly smaller amounts of about 1.75 million tonnes were treated both in 2017 and 2018. The largest share of it, 55% or about 0.95 million tonnes, went to re-refining (incl. exports to re-refining) in 2014. In 2017 and 2018 the treatment in re-refineries increased to about 1.08 million tonnes and 1.07 million tonnes or 61% and 62%. The second largest share, ca. 30% or about 0.54 million tonnes (2014) was treatment to fuels. Cement kilns, power plants, lime works and steel works together accounted for about 0.15 million tonnes or ca. 8%. A comparison with the data for the years 2017 and 2018 shows that a shift from fuels to re-refining took place. Only about 0.41 million tonnes and 0.42 million tonnes of waste oils (or 24%) were treated to fuels in 2017 and 2018. At the same time, the amounts treated in cement, lime industry, etc. slightly increased to about 0.19 million tonnes in 2017 and 2018. 'Other use' (e.g. flux oil) incl. 'Export other' accounted for about 3% in 2014 and 1% or less in 2017 and 2018.

A comparison between GEIR and Eurostat data proved to be difficult due to the more aggregated data of Eurostat. However, GEIR data on re-refining including other use and export add up to about 1.0 million tonnes to 1.1 million tonnes (58% to 65% of total waste oil) and thus are significantly lower than R2-R11 of Eurostat (about 1.9 to

2.0 million tonnes or 84% to 86%)[47]. At the same time, Eurostat's data on R1 of about 0.23 to 0.24 million tonnes is much lower than the sum of the GEIR data on cement, lime industry, etc. and fuels (about 0.69 million tonnes to 0.60 million tonnes).

The cement industry reported the treatment of about 255 000 tonnes of waste oil in the EU-28 in 2017 (CEMBUREAU 2019)[48]. These figures show that Eurostat's R1 figures from above (year 2016; incl. potential imports from non-EU countries and also incl. use as a fuel) are too low compared to the data from the cement industry. The GEIR figure on treatment of waste oils in cement kilns of about 68 000 tonnes[49] (excl. import from non-EU countries) in 2017 is much smaller than the figure of the cement industry.

Figure 10-2 Waste oil treatment total EU-28, input in tonnes/a, years 2014, 2017, 2018



Source: GEIR 2019

In the EU-28, ca. 0.7 million tonnes of re-refined base oil is produced according to GEIR (2019). By applying the base oil output in Table 7-2 and input into re-refining of about 1.08 million tonnes (from waste oil collection in the EU-28), in 2017 a total of about 683 000 tonnes of re-refined base oil is calculated. Additionally about 10 000

[47] Eurostat data might potentially include high water content from emulsions, however, the waste oil input into re-refining should have a water content of less than 10%. Thus, it is questionable whether the water content can explain the high amounts reported going to re-refining of Eurostat data.

[48] CEMBUREAU 2019 suggested that the vast majority of the waste used in the cement industry is generated within the EU.

[49] Even if adding the figures from lime and steel industry and power plants, 113 000 tonnes in 2017, the resulting totals, about 181 000 tonnes, would be still much smaller than the figure from the cement industry.

tonnes of re-refined base oils result from yearly imports of about 20 000 to 30 000 tonnes of waste oil (GEIR 2019).

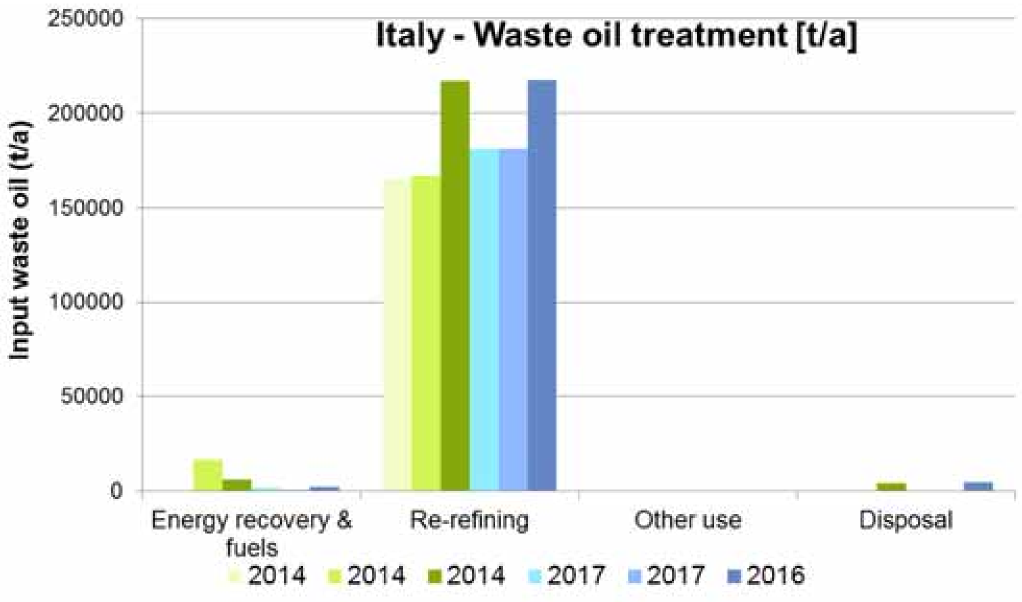
Thus, in total about 693 000 tonnes of re-refined base oil are produced in the EU-28 in 2017. Therefrom, about 80% is base oil API group I, 15% group II and 5% group III.

An analysis of the German statistics shows that a little bit more than one fourth (about 290 000 tonnes re-refined base oil or 28% in 2017) of base oils placed on the market in Germany originate from re-refined waste oils (BAFA 2016). In France, about 85 000 tonnes of re-refined base oil was produced in 2017 (about 8% of the total base oil PoM, see Figure 12-1).

In the following, waste oil treatment in selected MS is analysed on a more detailed level. Data from different data sources for 2014 and 2017 (respectively 2016) is presented for Italy, France, Germany and Spain (all four MS have re-refineries in their country). For each treatment process data from GEIR 2019 (first data set), data from the MS survey or other national data from desktop research (second data set) and Eurostat (third data set, [env_wastrt]) is presented; firstly for the year 2014 and secondly for 2017 (2016 in case of Eurostat data). Thus, a maximum of six data is presented per treatment process. While Eurostat data potentially includes imports, the other data sources do not. Exports are not considered. Re-refining in the case of Eurostat is R2-R11 and thus includes other reuses. All other data sources present 'Other use' separately and GEIR does not report any disposal.

Figure 10-3 presents the waste oil treatment in Italy. Almost all waste oil (91% to 100% depending on year and data source) is treated in re-refineries. In 2014, some waste oil (16 000 tonnes according to (Conou 2017)) went to energy recovery. This amount was further reduced in 2017 (2016) so that at least 97% was treated in re-refineries. Eurostat's figure on re-refining for 2014 (about 217 000 tonnes compared to about 215 000 tonnes of re-refining capacity in 2019) is about 50 000 tonnes higher than the figures from the other data sources. About one third of the difference might be explained by waste oil imports; see Chapter 9.

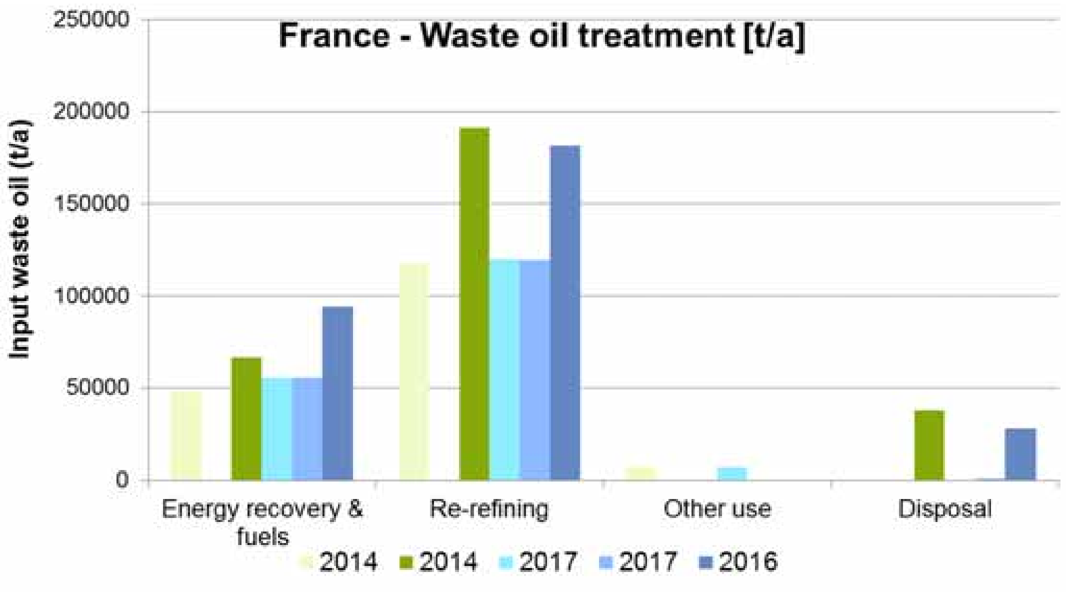
Figure 10-3 Italy waste oil treatment, input in tonnes/a, years 2014, 2017 (2016)



Source: GEIR 2019 (first data set), MS survey or other national data from desktop research (second data set), Eurostat (third data set); see Table 27-4, Table 27-8 in the Annex

Waste oil treatment in France in Figure 10-4 differs from the treatment flows in Italy. In France only between 60% and 68% (depending on year and data source) of the waste oil is treated in re-refineries. Instead, the share of the total waste oil going to Energy recovery is higher, between 22% and 32%. Total waste oil treatment data is much higher for Eurostat (about 300 000 tonnes) compared to the other data sources (up to about 180 000 tonnes treated in France). Differences cannot be explained by imports as France was still a net exporter in 2014; see Chapter 9. In France, re-refining capacities, 240 000 tonnes of waste oil, are much higher than the amount of waste oil going to re-refining, about 120 000 tonnes (which would correspond to the capacity of only one of the two re-refineries in France).

Figure 10-4 France waste oil treatment, input in tonnes/a, years 2014, 2017 (2016)

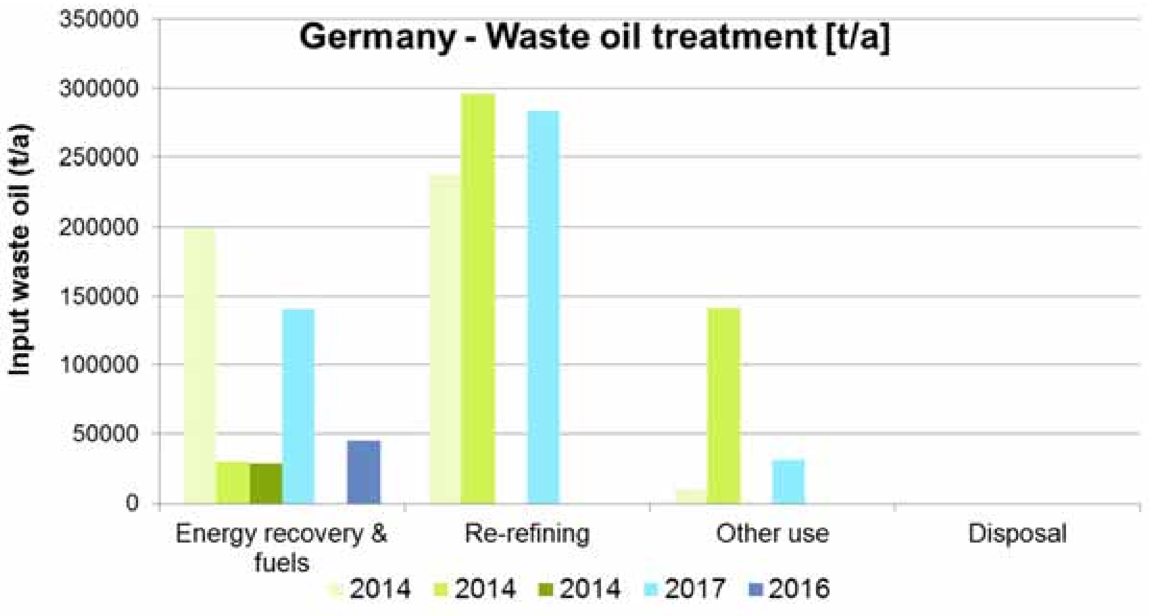


Source: GEIR 2019 (first data set), MS survey or other national data from desktop research (second data set), Eurostat (third data set); see Table 27-4, Table 27-8 in the Annex

Figure 10-5 presents the waste oil treatment in Germany. Between about 238 000 tonnes and 308 000 tonnes (depending on year and data source) of waste oil are treated annually in re-refineries. The data on re-refining from the different sources (apart from Eurostat data for re-refining which is not included in Figure 10-5) are in a similar range and account for about 48% to 63% of the total waste oil treated in Germany. Eurostat data on re-refining (about 990 000 tonnes, year 2014, and 870 000 tonnes, 2016) is considered much too high[50]. Depending on the year, roughly half of all waste oil collected goes to other treatment (mainly energy recovery and other use) than re-refining. Differences between energy recovery and other uses which occur for GEIR data and other sources may result from the different classification / allocation to the treatments processes. Re-refining capacities in Germany account for about 385 000 tonnes of waste oil input. This corresponds well with the figures from above (238 000 to 308 000 tonnes) when considering additional imports of waste oil for re-refining (about 130 000 tonnes, 2016) in Germany.

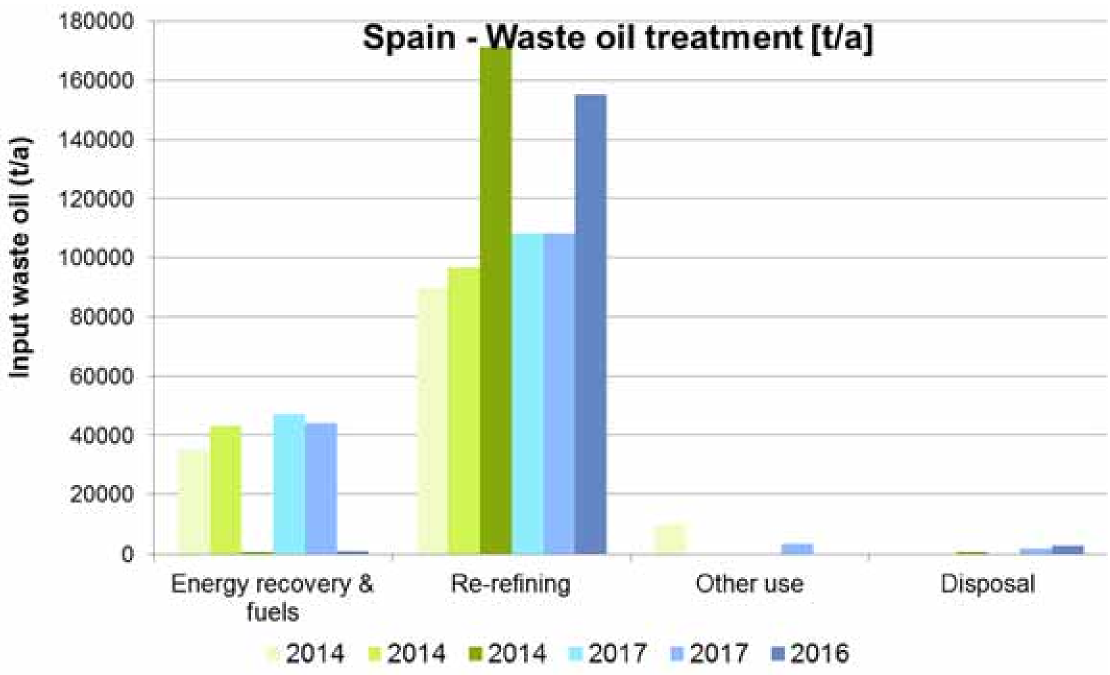
[50] Total input into re-refining about 1.08 million tonnes in EU-28 in 2017; thus 0.87 million tonnes in Germany are not realistic.

Figure 10-5 Germany waste oil treatment, input in tonnes/a, years 2014, 2017 (2016)



Source: GEIR 2019 (first data set), MS survey or other national data from desktop research (second data set), Eurostat (third data set); see Table 27-4, Table 27-8 in the Annex

Figure 10-6 Spain waste oil treatment, input in tonnes/a, years 2014, 2017 (2016)



Source: GEIR 2019 (first data set), MS survey or other national data from desktop research (second data set), Eurostat (third data set); see Table 27-4, Table 27-8 in the Annex

Figure 10-6 presents the waste oil treatment in Spain. Again, differences occur between Eurostat data and the other data sources. According to Eurostat data almost all waste oil (at least 97%) is treated in re-refineries. For the other data sources about

67% to 70% of the total waste oil treated in Spain goes to re-refining and about 26% to 31% goes to energy recovery and fuels. In the case of Spain, the total amounts of waste oil treated in Spain are comparatively similar for all data sources incl. Eurostat, ranging from about 135 000 tonnes to about 173 000 tonnes. Differences might at least partially be explained by net imports of waste oil to Spain.

Data on the waste oil treatment in Finland shows that more than 90% of the total waste oil goes to Finland's single re-refinery. Similar situations can be found in other MS with their own re-refineries; Greece (100% to re-refining) and Portugal (about 74% to re-refining in 2018). In Poland and the UK (both with own re-refineries) only comparably small amounts of the total waste oil collected go to re-refining. In particular in the UK, the data indicate that the capacities for re-refining are not used up.

11 Mass flows engine oils

Engine oils play an important role and are therefore considered separately in this chapter. On the one hand engine oils are of particular importance because of their large quantity while on the other hand they represent a homogenous waste fraction with well-established collection schemes and are well recyclable.

Engine oils represent the largest single application within lubricant oils and account for roughly one half of the total placed on the market; see Table 5-2.

In order to provide a comprehensive and structured picture of the specific engine oil flows, the Oeko-Institut developed a mass flow model. This model allows for the calculation of mass flows of engine oils from PoM (placed on the market) to the generation of waste oil. As a basic data source the model uses statistics and thus delivers results for all Member States and a timeline from 2012 to 2016. The model considers all types of road vehicles, however does not include other engine oils such as marine engine oils. It follows the life cycle approach of vehicles (production – use phase – end-of-life) and takes into account (first/re-) filling of the engine with oil, oil changes, draining of end-of-life vehicles (ELV) and losses from, e.g. the burning of engine oil during driving.

The mass flows do not consider the actual lifetime of the engine oils (and the vehicles), i.e. on the one hand fillings of newly produced vehicles and on the other hand draining of ELV in a given reference year are calculated at the same time. In this respect, differences between new registrations and ELV as well as import and export occur and are taken into account by calculating stock changes. More details on the calculation methodology are provided in Chapter 11.1.

As the mass flows are based on calculations, engine oil losses and collectable amounts of waste oils are considered. However, what is actually collected[51] as opposed to what in theory is collectable cannot be calculated in the model.

The treatment of the specific waste oil fraction of engine oils was not separately analysed. It is assumed that the resulting waste oils given their homogeneous composition and their comparatively low contamination can undergo treatment in re-refining plants to produce re-refined base oils.

11.1 Calculation model

In the following, data sources and main assumptions used for quantifying engine oil mass flows are described. The explanations follow the process stages and terminologies in Figure 11-1 and Figure 11-2. Data gaps were bridged by assumptions and calculations by the consultant (e.g. calculation of a mean value if a figure of the timeline was missing).

- **PoM new production (first filling of newly manufactured vehicles with engine oil):**

  ACEA production statistics of passenger cars and vehicles (https://www.acea.be/statistics/tag/category/passenger-cars-production; https://www.acea.be/statistics/tag/category/eu-production; https://www.acea.be/statistics/article/eu-commercial-vehicle-production);

[51] Relevant LoW codes, e.g. 130204* 'mineral-based chlorinated engine, gear and lubricating oils', do not consider engine oils separately.

4.4 l/passenger car (0.845 kg/l); 7 l/transporter (0.86 kg/l); 27 l/lorry (0.86 kg/l); 36 l/road tractor (0.86 kg/l) (https://www.oelberater.de/)

- **PoM oil change (oil change of engine oil):**

  stocks of vehicles (Eurostat: road_eqs_carmot, tran_r_vehst); 4.4 l/passenger car (0.845 kg/l); 7 l/transporter (0.86 kg/l); 27 l/lorry (0.86 kg/l); 36 l/road tractor (0.86 kg/l); 10 l/agricultural tractor (0.86 kg/l) (https://www.oelberater.de/); ca. 0.8 oil changes per year and passenger car (DAT-Report 2016), ca. 0.5 oil changes per year and transporter/lorries; ca. 1 oil change per year and tractor (https://www.oelberater.de/).

- **PoM consumption (compensation for losses from the burning of engine oil and oil filters, spill, oil residues in containers, etc.)[52]:**

  road traffic (million Vkm) by type of vehicle (Eurostat: road_tf_veh); passenger car 0.16 l/1000km (0.845 kg/l), lorries etc. 0.4 l/1000km (0.86 kg/l), motorcycles 0.16 l/1000km (0.86 kg/l) (UBA 2016). Compensation of oil losses (oil in oil filter, can, cloth etc.) of 0.05 l per oil change (estimate by Oeko-Institut)

- **Import / Export new + used vehicles (filling from imported new and used vehicles):**

  4.4 l/passenger car (0.845 kg/l); 7 l/transporter (0.86 kg/l); 27 l/lorry (0.86 kg/l); 36 l/road tractor (0.86 kg/l) (https://www.oelberater.de/)
  EUROSTAT - Comext (Import / Export, intraEU and extraEU) for motor vehicles:
  new motor cars (CN8: 87032110, 87032210; 87032319, 87032410, 87033110, 87033219, 87033319)
  used motor cars (CN8: 87032190, 87032290, 87032390, 87032490, 87033190, 87033290, 87033390)
  new transporter, lorry <=5t new (CN8: 87042131, 87042191, 87043131, 87043191)
  used transporter, lorry <=5t (CN8: 87042139, 87042199, 87043139, 87043199)
  new lorry, >5t but <=20t (CN8: 87042291, 87043291)
  used lorry, >5t but <=20t (CN8: 87042299, 87043299)
  new road tractor (CN8: 87042391)
  used road tractor (CN8: 87042399).

- **ELV collectable waste oil (generation of waste oils from the draining of end-of-life vehicles):**

  End-of-life vehicles, totals (Eurostat: env_waselvt); passenger car 4.9 l/car (0.845 kg/l) (UBA 2002); assumption: waste oils from the draining of other vehicles is negligible (e.g. due to export of used trucks).

- **Oil change collectable waste oil (generation of waste oils from the oil change of vehicles):**

  Assumption: A part of the refilling (compensation for losses due to burning of oil) takes place during oil change; thus the amount of waste oil collected during oil change is smaller than the amount PoM for oil change.

- **Losses:**

  Losses result from the refilling (burning) of engine oil and oil filters, spill, oil residues in containers, etc. Amount of PoM consumption plus a part of the refilling during oil change.

[52] 'PoM consumption' considers refilling / "topping-up" to compensate for losses from burning of engine oil during driving. A part of these losses will be compensated for during engine oil changes and the other part of the losses which is considered here will be compensated for by refilling / "topping-up".

- **Stock change:**
  Changes of the stock of vehicles; difference resulting from all input and output streams of the system.

(Methodological) uncertainties of this calculation mainly relate to:

- frequency of oil changes;
- frequency and amount of refilling (compensation of losses) of engine oil;
- filling quantities of engine oil for the different vehicle types;
- composition of vehicle fleets (share and age of the different vehicle types) and
- inconsistencies (e.g. vehicle kilometres of Portugal differ between Eurostat and the Portuguese statistical office) and data gaps of statistics.

These variables (apart from statistical data) are based on German literature sources and therefore do not take into account the specific national compositions (in particular the vehicle age) of vehicle fleets.

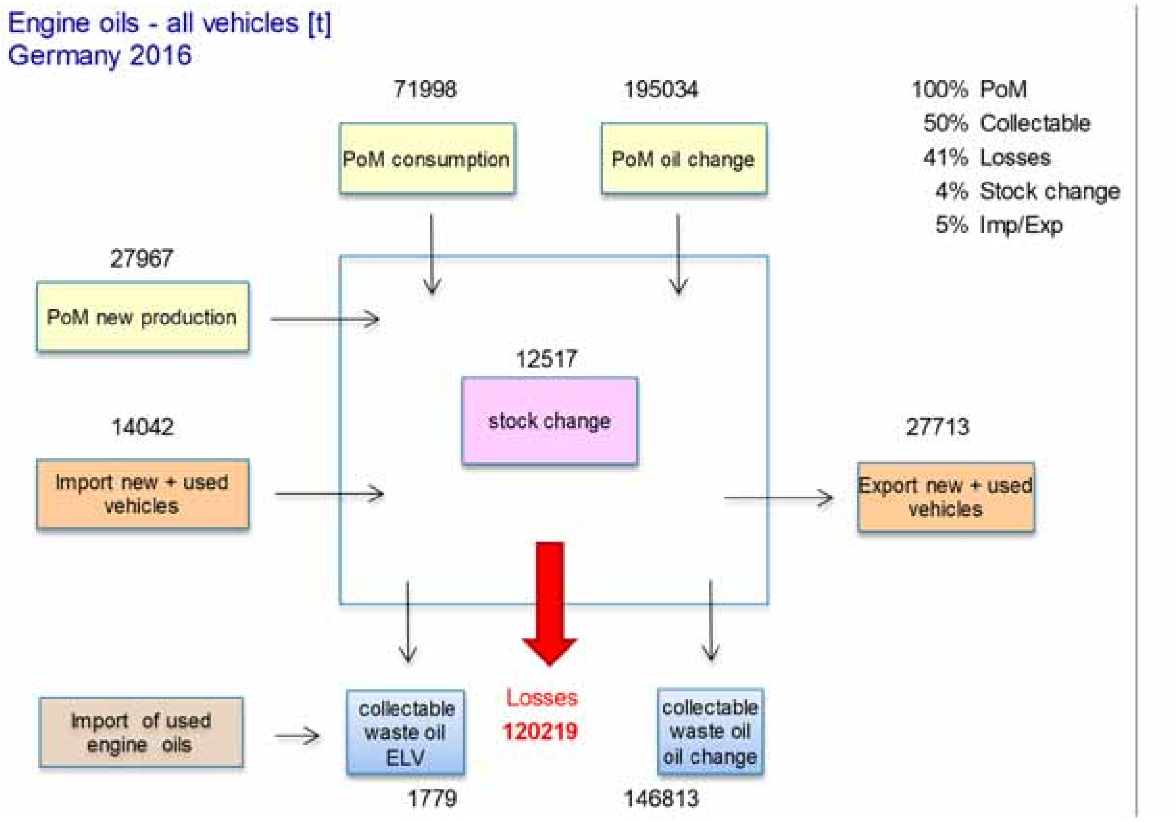
The first filling of newly produced vehicles presents a general uncertainty, as it is not clear whether these quantities of engine oil are taken into account in statistical data on lubricant consumption (in particular if vehicles are produced for export).

The model is compared and adjusted with amounts of engine oils PoM from national data sources from Belgium, Germany, France, Poland and Portugal (see Table 5-2). The national PoM data differ between 1% to 10% (exemption Poland, 18%) from the PoM calculated by model. The model was also compared with the methodology and the calculations for Germany in UBA (2016). In UBA (2016) a return rate of 51.9% was calculated for engine oil in Germany while in this model a rate of 50.4% results. The Belgium return rate calculated by the model of 46%, however, is considerably lower than the figures for Belgium in Table 6-1, about 68% to 73%.

11.2 Results on the engine oil mass flows

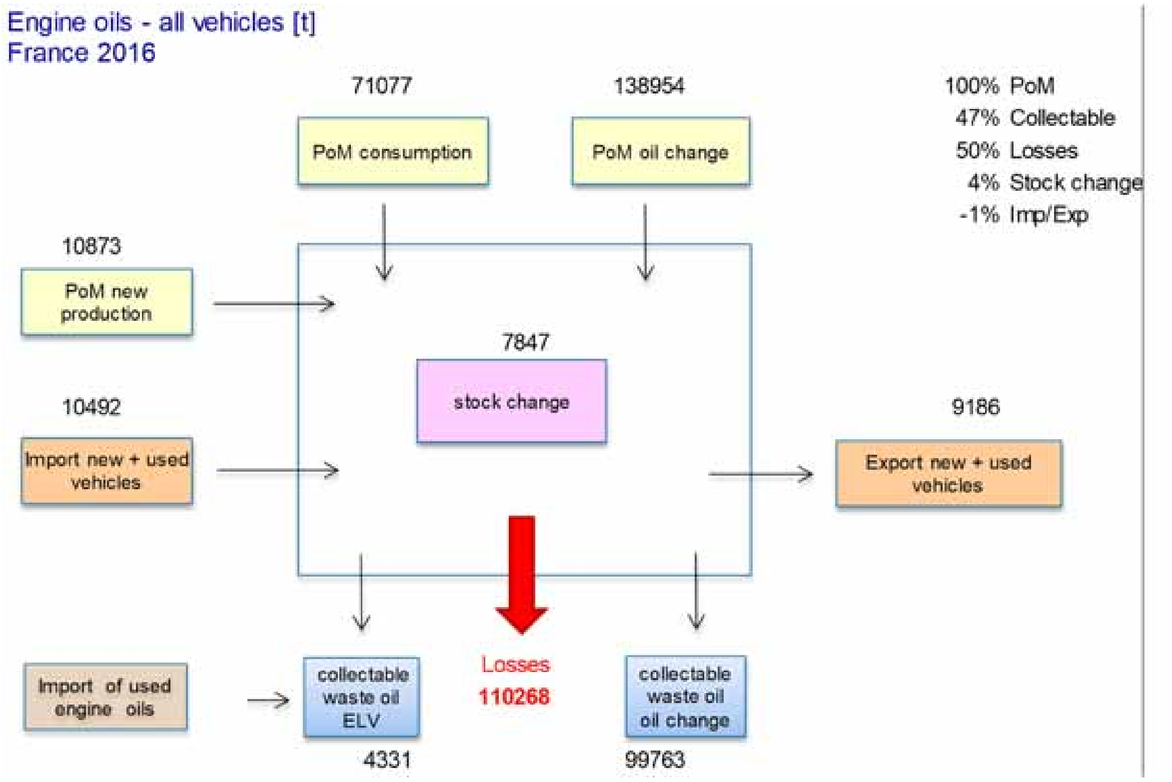
As an outcome of the modelling of the engine oil, mass flows data for all EU Member States (with the exception of Bulgaria due to missing statistical data) were calculated for the years 2012 to 2016. Results for the year 2016 are presented in mass flow diagrams for the examples of Germany and France in Figure 11-1 and Figure 11-2, and as an overview in Table 11-1 for all MS.

Figure 11-1 Results of the engine oil flow model for Germany 2016; amounts in tonnes



Source: Oeko-Institut

Figure 11-2 Results of the engine oil flow model for France 2016; amounts in tonnes



Source: Oeko-Institut

Table 11-1 shows that according to the model about 1.6 million tonnes of engine oils were PoM in the EU-28 (excl. Bulgaria) in 2016. Six MS, Germany, France, Spain, Italy, Poland and the UK, corresponding to their large vehicle fleets, account for around three-quarters of the total engine oil PoM in the EU-28.

About 0.8 million tonnes of engine oils are collectable in the EU-28. On average in the EU-28, 53% of the quantities placed on the market are collectable (return rate). Depending on the MS, however, the rates vary considerably between 41% and 67%. Unavoidable losses of about 43% result for the EU-28[53].

Oils PoM in newly produced vehicles account for only about 6% of the total engine oil PoM on the EU-28 level. However, this share can be much higher in MS with a large vehicle manufacturing industry. In Slovakia, the share of engine oil in newly produced vehicles (Volkswagen, PSA Peugeot Citroën, Kia Motors and Jaguar Land Rover) reaches 23% of all engine oil PoM in this MS.

Imports and exports of engine oils with new and used vehicles are equivalent to about 6% (import) and 7% (export) compared to the total amounts of engine oils PoM on EU-28 level.

Apart from the officially reported figures of used vehicles, there is an additional approximately 4 million of so called "vehicles of unknown whereabouts" (Mehlhart 2017). It is likely that a certain percentage of these vehicles is exported as well. The

[53] Stock changes add up to 100%.

share of vehicles with unknown whereabouts being exported outside the EU cannot be specified. However, it is assumed that the main share of "vehicles of unknown whereabouts" is treated within the EU (Mehlhart 2017). Assuming that a quarter of the 4 million vehicles with an unknown destination are exported to countries outside the EU-28, the engine oil exported together with the used vehicles would account for about 3 700 tonnes of lubricant. Three quarters of the 4 million vehicles or about 11 000 tonnes of lubricant are additionally exported within the EU-28. However, as shown in (Mehlhart 2017), this cannot be proved and is therefore not considered in the mass flows.

Net imports (imports minus exports) and net exports (imports minus exports) vary considerably for individual MS and reach up to 21% of the total engine oil PoM in the given MS. Slovakia, with 21%, has the highest share of all net exporters and Ireland, with 15%, has the highest share of all net importers.

The mass flow of collectable waste oil is dominated by waste oils resulting from oil changes. Waste oils from ELV account for only about 3% of the total collectable waste oil.

Table 11-1 Results of the engine oil flow model by MS; year 2016; amounts in tonnes

2016 / tonnes	PoM new production	PoM oil change	PoM consumption	Import new/used vehicles	Export new/used vehicles	Losses	ELV collectable waste oil	Oil change collectable waste oil	Stock change	Return rate	Losses
BE	2590	23724	11685	9483	9758	18383	441	17026	1874	46%	48%
BG*											
CZ	5131	21542	6238	1365	5831	9636	604	18144	60	57%	29%
DK	0	9728	5347	1948	1572	8674	369	6402	8	45%	58%
DE	27967	195034	71998	14042	27713	120219	1779	146813	12517	50%	41%
EE	0	3081	1100	252	95	1793	46	2387	110	58%	43%
IE	0	8879	5711	2150	24	8951	407	5640	1719	41%	61%
EL	0	24482	12394	730	19	18297	193	18579	518	51%	50%
ES	13070	102978	23322	5979	13415	39170	2532	87131	3103	64%	28%
FR	10873	138954	71077	10492	9186	110268	4331	99763	7847	47%	50%
HR	0	5986	2084	381	113	3544	0	4526	268	56%	44%
IT	5610	154534	62615	9105	5251	100064	4053	117085	5411	54%	45%
CY	0	2088	1045	216	7	1601	21	1532	188	50%	51%
LV	0	2868	1215	173	69	2026	33	2057	70	51%	50%
LT	0	5459	1740	482	187	2888	88	4311	207	61%	40%
LU	0	1560	596	378	164	977	8	1179	206	55%	45%
HU	1930	14369	5441	1103	2436	8110	63	11700	535	54%	37%
MT	0	1203	524	119	62	820	0	907	57	53%	47%
NL	2785	31977	15550	4402	3182	24468	780	23060	3225	47%	49%
AT	492	24639	8936	2334	1234	14494	199	19081	1393	57%	43%

2016 / tonnes	PoM new production	PoM oil change	PoM consumption	Import new/used vehicles	Export new/used vehicles	Losses	ELV collectable waste oil	Oil change collectable waste oil	Stock change	Return rate	Losses
PL	3411	96885	25403	2724	3758	40566	1980	81723	398	67%	32%
PT	827	20947	11333	1496	809	16985	367	15295	1148	47%	51%
RO	1321	23814	6097	660	1589	9409	173	20502	218	66%	30%
SI	492	4376	2080	1309	1963	3478	26	2978	-188	43%	50%
SK	3827	9168	3736	1545	4980	5918	153	6986	240	43%	35%
FI	173	15010	5523	807	343	8838	474	11695	162	59%	43%
SE	2107	17792	8302	2350	1632	13621	774	12473	2051	47%	48%
UK	7105	118067	59219	13850	14574	93043	4567	84243	1814	48%	50%
EU-28	**89711**	**1079143**	**430313**	**89874**	**109964**	**686242**	**24461**	**823214**	**45159**	**53%**	**44%**

*: Due to many data gaps Bulgaria's data is not displayed.
Source: Oeko-Institut

12 Mass flows of base oil, lubricant oil and waste oils

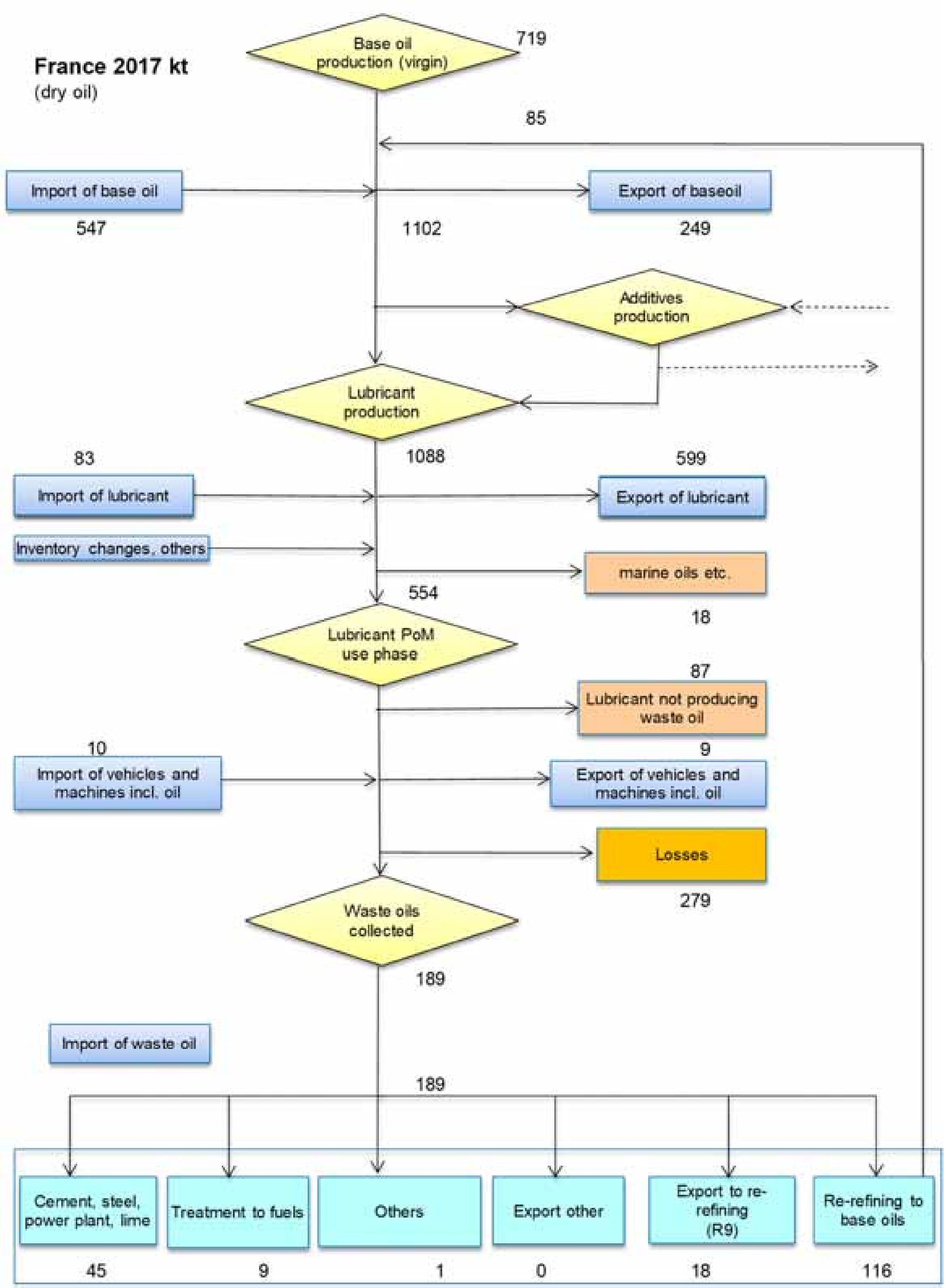
In the following, the various life cycle stages of oils, which were described in detail in the previous chapters, are summarized. In result, comprehensive mass flows from the production of oil to the treatment of waste oil were developed.

Figure 12-1 presents the country-specific oil mass flows for the example of France for the year 2017. The oil flows on the EU-28 level are shown in Figure 12-2. The detailed comprehensive results which were also used to develop the mass flow diagrams are listed in Table 27-4 in the Annex.

In France about 0.72 million tonnes of virgin base oils were produced in 2017. Additionally, about 85 000 tonnes of re-refined base oil resulting from regeneration of waste oil were produced. France is a net importer of about 0.3 million tonnes of base oil. Thus, in total about 1.1 million tonnes of base oil were PoM in 2017. A part of the base oil is used for additives. Including about 23% of additives, a total of about 1.1 million tonnes of lubricant oils were produced in France in 2017. France is a net exporter of lubricant oils of about 0.5 million tonnes in 2017. In total, about 0.55 million tonnes of lubricant oils were placed on the market in France in 2017. About 0.26 million tonnes of the amount PoM are collectable according to GEIR (2019). This means a return rate of about 47%. About 0.19 million tonnes of waste oil were actually collected in 2017. 0.19 million tonnes of waste oil collected corresponds to about 34% of the amount PoM and about 73% of the collectable waste oil.

About 71% of the total collected waste oil is re-refined to base oil (incl. export to re-refining). The remaining waste oil is treated for energy recovery in, e.g. cement kilns and for use as a fuel.

Figure 12-1 (Waste) oil flows, France 2017; amounts in kilo tonnes



Source: Oeko-Institut

Overall in the EU-28, an estimated 8 million tonnes of virgin base oils were produced. Additionally, about 0.68 million tonnes of re-refined base oil resulting from the regeneration of waste oil in the EU-28 were produced. Today's capacities are still dominated by API group I base oil. However, a clear shift to group II (and higher base oil groups) is taking place in the EU-28. This is underlined by the shutdown of two group I base oil plants in the Netherlands in 2016, while the now largest base oil plant opened in Rotterdam in 2019 and is producing group II base oil (capacity of 1 million tonnes). Furthermore, additional capacities of about 200 000 tonnes for groups II and III have been announced for Spain for the year 2020.

The EU-28 is a net exporter of base oil. The flows in in Figure 12-2 suggest that net exports of base oil and use for additives together account for about 4 million tonnes of base oil in 2017[54]. The largest part of these 4 million tonnes of base oil can be allocated to net exports. French data shows that lubricants consist of about 23% of additives, which means that about 1.4 million tonnes of additives are used for lubricant production in the EU-28, see Figure 12-2[55]. Overall, a production of about 6 million tonnes of lubricant oils in the EU-28 is calculated. The EU-28 is also a net exporter of lubricant oils of about 1.5 million tonnes in 2017. Italy is the main net exporter (extra EU trade) of lubricants (about 0.8 million tonnes in 2018).

In total, about 4.3 million tonnes of lubricant oils were placed on the market in the EU-28 in 2017. Marine oils of about 0.35 million tonnes are not taken into account, as their use due to worldwide maritime transport is not traceable. Germany, the UK, France, Spain and Italy are the main consumers in the EU-28 and together placed about 71% of the total lubricant consumption on the market.

During the use phase lubricants are imported and exported mainly within new and used vehicles but also other products. Such imports and exports from and to MS on EU level should balance each other out. However, imports and exports influence the amount of lubricants PoM on MS level.

Most of the losses which occur during the use phase of lubricants are unavoidable. This includes mainly process oils and greases or burning of engine oil during driving. Unavoidable losses of engine oil account for about 0.7 million tonnes (see Chapter 11.2). In total about 2.0 million tonnes of waste oils are collectable. This corresponds to an overall return rate (share of collectable waste oils of the total consumption of lubricants) of about 47%.

Other losses can occur due to improper management of waste oils and are considered avoidable. On the level of the EU-28, differentiation between avoidable and unavoidable losses is only partially possible (see engine oil above) and the total losses account for about 2.7 million tonnes of waste oils. These losses are calculated from the difference of the amount collected, about 1.6 million tonnes, and the amount PoM, 4.3 million tonnes. Overall, about 38% of the amount PoM in the EU-28 was collected as waste oil. This corresponds to a collection rate of about 82% (share of the actual collected waste oil of the collectable waste oil). Thus, unavoidable and avoidable losses totalling 62% of the amount PoM result in the EU-28.

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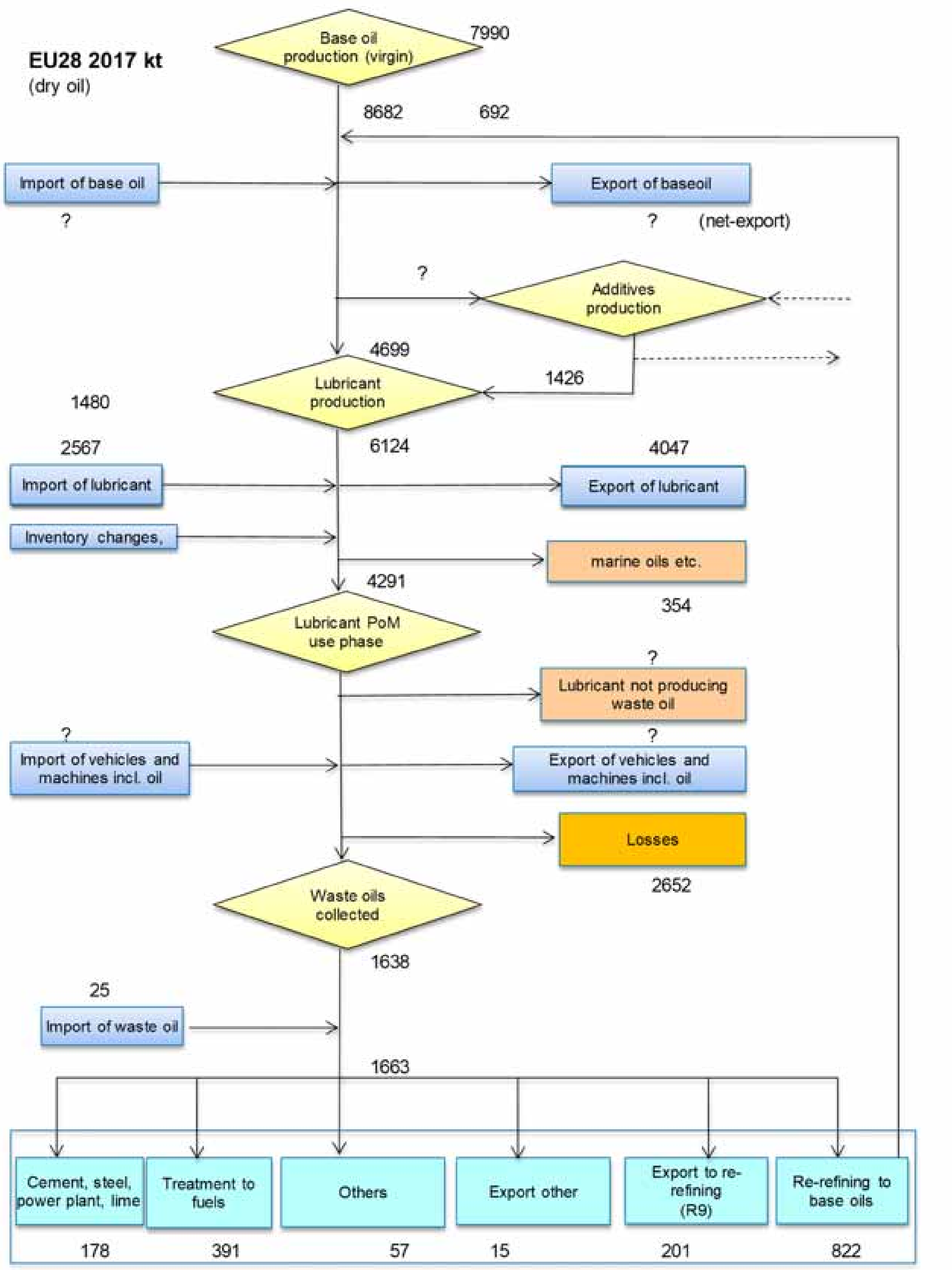
[54] Base oil production is based on data from 2013 to 2018. Lubricant production can only be back-calculated from lubricant consumption. Base oil imports/exports and the use of base oil for additives are unknown and can only be estimated as the remaining difference.

[55] A part of the additives originates from the 4 million tonnes of base oil mentioned afore. Imports and exports of additives and other chemical production of additives also need to be considered. Therefore, the actual mass flows of the additives cannot be represented.

The French data in Figure 12-1 allows for a more detailed presentation of mass flows related to the use phase. Process oils, greases, two-stroke engine oils and other industrial oil not used for lubrication are considered to be not producing waste oil and account in a total for about 87 000 tonnes or 16% of the amount PoM in France in 2017. About 189 000 tonnes of waste oils are collected in France which is about 34% of the amount PoM. Thus, losses of about 279 000 tonnes or about 50% of PoM occur. This includes unavoidable losses of about half of the amount of engine oils PoM (between about 220 000 tonnes to 240 000 tonnes engine oils PoM in 2016).

Imports of waste oils into the EU-28 are rather small and are estimated to about 20 000 to 30 000 tonnes per year. In total about 1.6 million tonnes of waste oils were treated in the EU-28 in 2017. The main share of it, about 61%, was input into re-refineries and resulted in about 0.68 million tonnes of re-refined base oil. About 24% of total waste oil was treated to produce fuels and about 11%, the third highest share, was used for energy recovery in cement, lime, steel and power plants.

Figure 12-2 (Waste) oil flows, EU-28 2017; amounts in kilo tonnes



Source: Oeko-Institut

13 Treatment processes and technologies

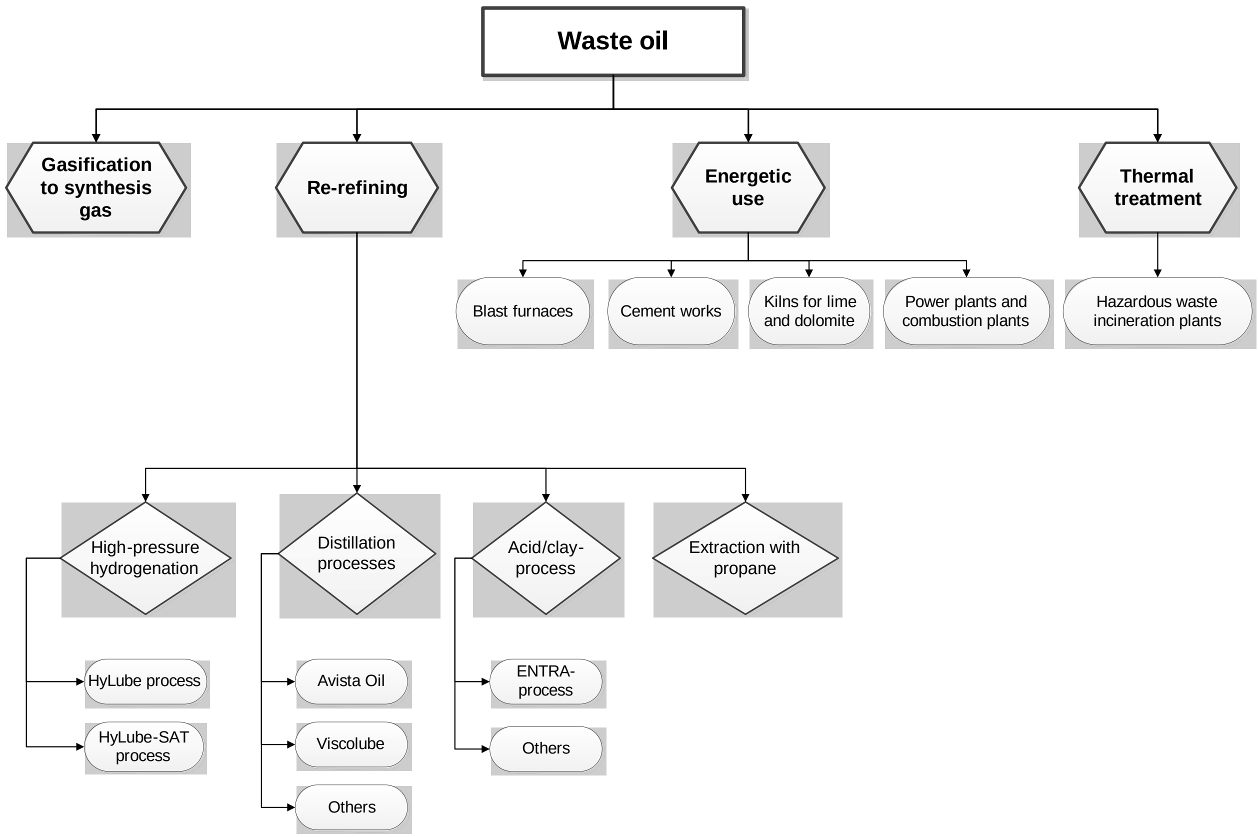
The vast majority of the waste oils produced are contaminated mineral oils, which essentially consist of liquid mixtures of saturated hydrocarbons from the distillation and refining of crude oil. A small proportion is synthetic oils. Depending on the application and origin, the waste oils contain different additives and active agents, the cracking and oxidation products resulting from ageing as well as foreign substances from the application processes (e.g. metal abrasion).

The waste oils resulting from the use as e.g. engine oil, gear oil, insulating oil, heat transmission oil or hydraulic oil have only small water contents and can go directly into the waste oil treatment. The emulsions and solutions used in metalworking, on the other hand, contain only small amounts of oil and consist predominantly of water. They are therefore described separately in Chapter 13.2.3. However, the oils obtained after separation of the main water content can be treated like waste oil.

13.1 Waste oil treatment processes

Figure 13-1 provides a schematic overview on possible treatment processes of waste oils. The different treatment processes are described in the following sub-sections.

Figure 13-1 Schematic overview on treatment processes of waste oil



Source: Oeko-Institut

13.1.1 Re-refining of waste oils

Various processes are used in the re-refining of waste oil. The main base oils produced are group I and II base oils according to the classification of the American Petroleum

Institute (API). In Germany, a plant is also in operation in which Group III base oil is produced (HyLube-SAT process).

13.1.2 High-pressure hydrogenation process

In the first step, the waste oil is mixed with hot hydrogen, whereby 50-70% of the waste oil passes into the gas phase and a sump residue remains.

The oil vapours enter the high-pressure hydrogenation reactor. There, the direct contact hydrogenation (HyLube process) takes place with special catalysts at 60-80 bar and 300-350 °C. The metal compounds and the sulfur, nitrogen and chlorine compounds of the additives are removed and aromatic compounds are saturated. The oil components are then separated from the reaction products and the circulating gas and separated in a fractionation column into base oils with different viscosities and into the by-products petrol and diesel.

The sump residue is separated in a stripping column with steam into heavy oil and other oil vapours.

Using this process, the Elsteraue plant of PURAGLOBE GmbH can produce approx. 90 000 tonnes of base oil and approx. 50 000 tonnes of mineral oil products (see Table 13-1) per year from 150 000 tonnes of waste oil. In 2017, 140 000 tonnes of waste oil were processed into 86 500 tonnes of Group II base oil. (Martens/Goldmann 2016; Puraglobe 2019; N.N. 2019)

The HyLube-SAT process of PURALUBE Raffinerie 3 GmbH, which went into operation in 2017, produces Group III base oil from Group II base oil. The base oil is compressed to 100 bar and treated with high-purity hydrogen in two high-pressure hydrogenation reactors equipped with a newly developed platinum catalyst system. At the system voltage in the hot and cold separator, the resulting sulfides and halides are washed out and the excess hydrogen is returned to the beginning of the cycle. Thus, the yield of saturated hydrocarbons due to the hydrogenation increases and the content of sulfur decreases (as sulphides). According to Schüppel, 2018 the yield of resulting Group III base oil is about 100%.

Since 2017, 45 000 t/a of Group III base oil can be produced from waste oils via Group II using this process.

(Schüppel 2018; N.N. 2019)

13.1.3 Distillation processes

Various combinations of vacuum distillation and distillation at atmospheric pressure are used for the regeneration of waste oils by distillation. For vacuum distillation are used, among others, cyclone evaporators and thin film evaporators. Refining is also carried out by solvent-extraction or hydrofinishing. Due to the large number of possible combinations, only two processes are described below.

Avista Oil (not process designation but a company name)

Avista Oil operates waste oil refineries in Germany and Denmark, among other countries.

All waste oils are heat treated in distillation systems under light vacuum pressure. Water and volatile components are distilled off.

The dried waste oil is subjected to a multi-stage distillation in which first the fraction similar to the light heating oil is distilled off. The bottom product located in the base of the column is then separated by a process known as flash distillation, consisting of a flash drum and two thin-film evaporators. The base oil crude distillate obtained in this way already has base oil character and is dark brownish-transparent.

In order to remove the undesirable components (e.g. PAHs) in the base oil starting fractions, they are treated with the help of a solvent in a liquid-liquid extraction plant. The base oil, which is now free of impurities, forms the refining phase with a low solvent content. The solvent enriched with the impurities forms the extract phase. Both the obtained raffinate and extract phases are separated from the solvent in subsequent distillation units. The completely recovered solvent can thus be used again in the extraction process. The refined products obtained in this way are sold directly as base oil or processed further for various lubricants (e.g. engine oils, hydraulic oils, gear oils, industrial lubricants).

Avista Oil can process approx. 160 000 tonnes of waste oil per year into base oil and secondary products at its plants in Kalundborg (Denmark) and Dollbergen (Germany, former Mineralöl-Raffinerie Dollbergen GmbH). In addition, 50 000 tonnes of waste oil per year can be processed into fuels at the Dollbergen plant. (Avista Oil 2019; GEIR 2019))

Viscolube (no process designation but company name)

Viscolube (now ITELYUM) operates two waste oil refineries in Italy. The procedure at the Pieve Fissiraga (Lodi) site can be described as follows.

The waste oil is distilled in a vacuum column to separate water and volatile components.

The dried waste oil is distilled at 360°C in a vacuum de-asphalting column (TDA) where the asphaltic and bituminous products remain on the bottom. Three fractions with different viscosities are extracted as well as gas oil at the top of the column. The three fractions and the gas oil are fed into the hydrofinishing process.

The final result is a clear oil with a very low sulphur content.

According to Viscolube, the two plants in Pieve Fissiraga and Ceccano (Italy) can process around 190 000 tonnes of waste oil per year. Other sources indicate 214 000 tonnes/a. (Fehrenbach 2005; Viscolube 2019; GEIR 2019)

13.1.4 Acid / clay process

The acid/clay process is the oldest process for the re-refining of waste oils. Due to the high amount of waste it is hardly used today. The only known method that can be assigned to this category and is still in use today is the ENTRA method described below.

ENTRA-process

The ENTRA process developed by SÜDÖL Mineralöl-Raffinerie is a further development of the Meinken process. In the first step, light boilers and water are separated at 160 °C under normal pressure. The drying oil is then evaporated in a tube reactor at 5-10 mbar. Solids and low-volatility additives are discharged and the gas phase is condensed. The condensate is post-treated with sulphuric acid, clay and 50% sodium hydroxide solution and fractionally distilled.

The advantages of the ENTRA process compared to the Meinken process are the higher product yield, the significantly lower use of sulphuric acid and clay and the associated significant reduction of waste (acid sludge and loaded clay).

With this process Südöl GmbH can process approx. 30 000 tonnes of waste oil per year. The products manufactured are base oil (40%), flux oil (20%) and gas oil (20%). The secondary products are flux oil ZR (8%), heavy oil ZR (3%) and light boilers (1%).

(Möller 1999; Cieslik 2016)

13.1.5 Extraction with compressed propane

In the first step, light boilers and water are separated in an evaporator. The waste oil is then pumped into a countercurrent extraction column. There the oil component is extracted by means of liquid propane at 95 bar and 150 °C and separated from solids and a heavy oil. The oil component is then hydrogenated at 250 °C (hydrofinishing) and the organic chlorine and sulphur compounds are converted into hydrochloric acid and hydrogen sulphide with the aid of a catalyst. By reducing the pressure in a separator to 18 bar, a pure oil phase forms as a recycling product (base oil) and a gas phase, which is cleaned by washing with sodium hydroxide solution and then separated into water, hydrogen and propane. Hydrogen and propane are circulated.

There is also a process where the residue from the propane extraction is thermally treated again and subjected to a second propane extraction to recover more oil.

In another process, the waste oil is pre-treated with reagents and catalysts prior to propane extraction. During propane extraction, water and heavy oil/asphalt are separated. Atmospheric and vacuum distillation is used to separate the light fractions and the base oils.

(Martens/Goldmann 2016; European Commission 2006; Janosfia 1988)

13.2 Other uses and treatment methods

13.2.1 Gasification to synthesis gas

The gasification of waste oil takes place in entrained flow gasifiers. After quenching and purification, the resulting gas mixture can be used as fuel gas or synthesis gas for the production of methanol. (Martens/Goldmann 2016)

No information is available on the relevance of this process.

13.2.2 Energetic use and thermal treatment

Waste oil can easily be used in cement works as well as in kilns for lime and dolomite etc. Waste oil is also used as a substitute fuel in power plants and combustion plants. A simple pre-treatment (separation of water and solids) is required. When used in blast furnaces, waste oil serves not only as a source of energy but also as a reducing agent and replaces heavy oil, coke and natural gas. (Martens/Goldmann 2016)

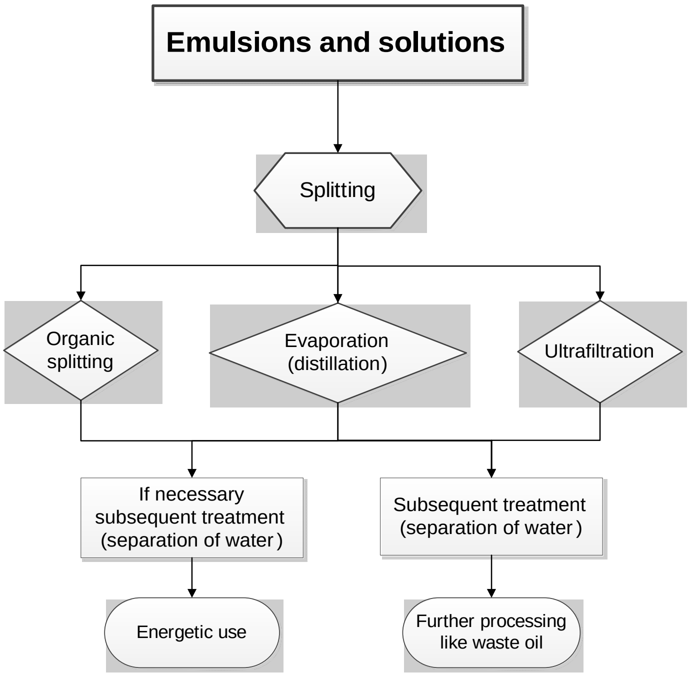
Treatment in hazardous waste incineration plants also takes place.

13.2.3 Treatment processes of emulsions and solutions

Emulsions and solutions from metalworking containing mineral oils have a high water content. As the emulsions do not separate oil and water, they must be split before separation. Various processes are available for splitting the emulsions, but only organic splitting, evaporation and ultrafiltration are relevant. As a rule, the separated oil fraction is used as substitute fuels.

Figure 13-1 shows a schematic overview on possible treatment processes of emulsions and solutions. The different treatment processes are described in the following sub-sections.

Figure 13-2 Schematic overview on treatment processes of emulsions and solutions



Source: Oeko-Institut

13.2.4 Organic splitting

Synthetic, highly polymeric substances, mostly tertiary and quaternary polyamines or polyamides, are used for splitting. These neutralize the stabilizing effect of the emulsifiers by neutralizing their charge. With this technique approx. 90% of the emulsified oil can be separated. (ATZ-EVUS 2001)

13.2.5 Evaporation (distillation)

The evaporation process is mainly used for mixed emulsions containing different surfactants. Thin film or circulation evaporators are the preferred evaporators. Heating already causes a slight emulsion splitting. However, vacuum evaporation separates most of the water. The oil content of the emulsion then amounts to approx. 20%. For further treatment, centrifuges are used which supply an oil phase with 25% residual water. As a subsequent process step, however, further dewatering can take place in a desorber in which heated air is blown in via a nozzle base, which is saturated with water vapour and thus dewaters the oil to 5% water. (Martens/Goldmann 2016)

13.2.6 Ultrafiltration

In ultrafiltration, the emulsion to be separated flows over a porous membrane at high speed under pressure (3 - 10 bar). The water, water-soluble salts and water-soluble organic substances pass through the pores of the membrane (permeate) and oils, fats, hydrophobic emulsifiers, metal hydroxides and abrasive particles remain in the retentate. With ultrafiltration, oil contents of 30 - 50% can be achieved in the retentate phase. However, the retentate can also be enriched to approx. 90% oil by thin film evaporation or centrifugation. (Denz 2009b; Martens/Goldmann 2016; LUBW 1996)

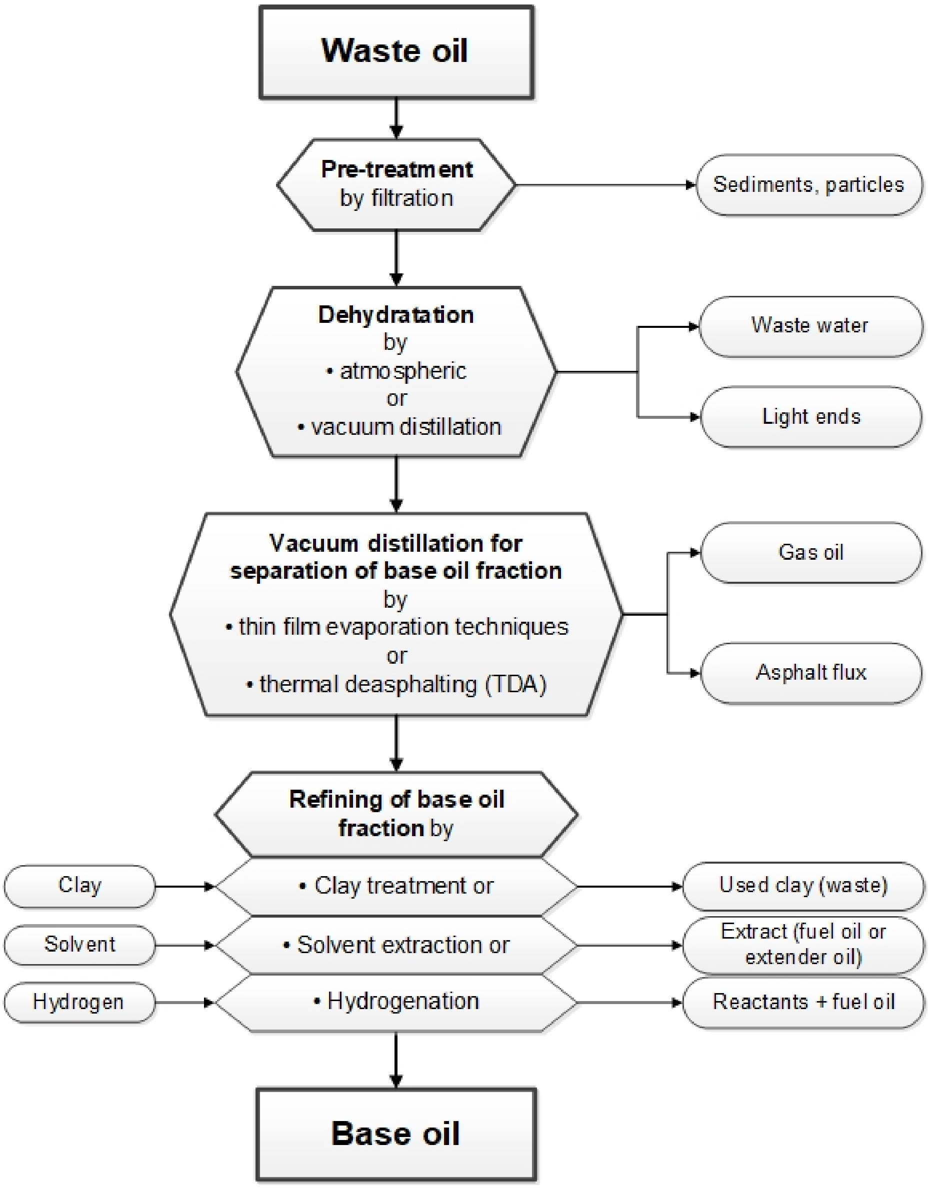
13.2.7 Best practice regeneration of waste oil

For the treatment of waste oils, regeneration resulting in re-refined base oil is considered to be the best practice, in particular with regard to the circular economy and waste hierarchy. A schematic overview on the re-refining process is provided in Figure 13-3. Details on specific processes were already described in the sections above, see subchapter 13.1.

Re-refining of waste oil is generally a distillation process for the separation of the base oil fraction. The actual distillation is preceded by pre-treatment processes to separate sediments and water. The final refining of the base oil fraction determines the quality of the base oil.

The output of the re-refining process and the share of the different products depend on the input (composition of waste oil) and the specific technology of the plant. Today, re-refining plants produce base oils of the API groups I, II and III. The main product, the base oils, makes up for about 60% to 75% of the total input. On average, an output of about 63% base oils results based on the total waste oil input, see Table 7-2.

Figure 13-3 Schematic overview on the re-refining process of waste oil



Sources: GEIR 2019, Oeko-Institut

Table 13-1 shows waste oil regeneration processes for the selection of best practice. The Entra process may be considered a separate technology which does not fit into the scheme in Figure 13-3. The entire high-pressure hydrogenation process (Hy-Lube/HyLube-SAT) is principally a distillation process as generally described in Figure 13-3. It can be characterized by its hydrogenation step of the base oil fraction. The other distillation processes in Table 13-1 can apply the clay treatment for the refining of base oil as assumed for Avista Oil, Dollbergen, and potentially also other processes.

When considering best practices of waste oil re-refining the main focus is on the share of regenerated base oil and its quality. The (distillation) processes listed in the table are only examples and were also selected because data availability was best for these processes. Distillation processes vary from plant to plant, differences are generally small and comparable results to those listed in the table can be achieved.

The total output of usable oils and other products differs only slightly between the different processes. Differences, however, occur in the regenerated shares of base oil, the base oil groups and in the by-products. The regenerated base oil shares are between 60% and 70% in most processes. Only the Entra process, at 40%, is significantly lower. However, since the share of recoverable base oil and its quality depend on the quality of the waste oil input, the difference may also be due to, at least in part, the fact that poorer quality waste oil might be used in the Entra process.

The additional waste produced is highest in the Entra process. However, it can be recycled. The acid tar is incinerated, the resulting SO_2 recovered and used to produce sulphuric acid again. The used clay is used as a fuel in the cement industry (using the oil component) and the remaining part is used as a pure alumina component of the cement to be produced [LUBW 1996]. This also applies to other processes if the refining of base oil is carried out with clay and thus a small amount of used clay is produced as additional waste.

Based on the above and Table 13-1, the HyLube process in combination with the HyLube SAT process is considered to be the best process. It is currently the only process that produces API group III base oil.

Table 13-1 Overview on selected processes of waste oil regeneration

Selected technical process	**Acid / clay (Entra-process)[1]**	**High-pressure hydrogenation process[2]**		**Distillation processes[3]**	
		HyLube-process	HyLube-SAT-process	Avista Oil (Dollbergen plant)	Viscolube (Pieve Fissiraga plant)
Input	Waste oil	Waste oil	Base oil Group II	Waste oil	Waste oil
Output					
Primary product					
Base oil [%]	40				65-70
Base oil Group II [%]		> 60			
Base oil Group III [%]			100		
Base oil Group I/I+ [%]				59	
By- product					
Gas oil [%]	20			15	3-4
Flux oil [%]	28				
Fuel oil [%]				5	
Petrol [%]					
Diesel [%]		33			
Heavy oil [%]	3				6-7
Light ends [%]	1			2	14

Selected technical process	**Acid / clay (Entra-process)[1]**	**High-pressure hydrogenation process[2]**		**Distillation processes[3]**	
Asphalt [%]				13	
Additional waste		Unknown	Unknown		Unknown
Acid sludge [kg/t dry oil]	19				
Used clay [kg/t dry oil]	23			small quantities if treatment with clay	

The rest adding up to 100% are water and sediments.
Avista oil and Viscolube are companies not processes.
Sources:
[1] Möller 1999, Cieslik 2016
[2] Puraglobe 2019, Schüppel 2018
[3] Bruhnke 2008, Fehrenbach 2005

Apart from the regeneration of waste oils the treatment of emulsions shall also be considered. Table 11-1 provides an overview of the three relevant processes, with the organic splitting being the most common process. For more details on the processes please refer to Chapter 13.2.3. A comparison of the processes and its advantages and disadvantages are given in Table 11-1. A best practice selection, however, is not feasible since the advantages and disadvantages are too diverse in their nature.

Table 13-2 Overview on selected treatment processes of emulsions

Technical process	Pros	Cons	Residual oil in water
Evaporation (distillation)	Material recovery	High energy consumption	< 20 mg/l
	Thermally usable or treatable oil phase	Disposal of residues if they cannot be recycled	
	Allows removal of refractory and/or toxic organic compounds		
	No use of chemicals		
Ultrafiltration	Can be used for emulsion separation regardless of type, concentration or stability	High energy consumption for pumps	< 5 mg/l
	Use of chemicals only for membrane cleaning	The shelf life of organic membranes depends on temperature, pH value and chemicals. However, the durability of ceramic membranes is significantly higher.	
Organic splitting	Low energy consumption	Use of chemicals	< 50 mg/l

Sources: Wagner et al. 2010, ATZ-EVUS 2001

14 Re-refining economics

Overall in the EU-28, less than 8 million tonnes of virgin base oils were produced according to estimates based on the years 2013 to 2018. More than half of this was produced for the EU market and the largest part of the remaining base oils is exported to the global market, see Chapter 12. Generally, the base oils market represents a global market. *"The balance between production and consumption is highly commercially complex business involving factors such as base oil quality, price, supply, availability, transportation costs, etc."* (FuelsEurope 2019). Re-refined base oils accounted for about 0.6 million tonnes in the EU-28 in 2017. This corresponds only to about 8% of the virgin base oil production. The market for re-refined base oil from the re-refiners in the EU-28, however, is considered more limited and European in scope.

As a recycled product, the composition and specification of the re-refined base oil depends on the composition of the waste oil input into the re-refinery and the applied technical process of the re-refinery. Just as the quality of the re-refined base oil is different, the quality standards for lubricant oil vary from lower to high standards and depend on the respective application. Finding a customer in the lubricant production with matching quality requirements might have previously been sometimes challenging for re-refined base oil. All the more, as general reservations about a recycled product often had to be overcome. Consequently, prices for re-refined base oil were lower than prices for virgin base oil. *"Typically, re-refined base oil attracts a price 20% to 25% below that which might have been expected for a product with similar viscosity and related features supplied by crude oil refiners."* (Oakdene Hollins 2010). The proof by analytical means that the re-refined base oil meets the high quality standards of lubricant formulations and direct business relations are assumed to have helped in overcoming potential barriers. Meanwhile a trend in favour of re-refined base oil might become established. Re-refined base oil as a "sustainable" or "green" product can also present a sales argument (GEIR 2019).

Considering economic aspects, virgin base oil prices are linked to crude oil prices (about 60 to 80 US Dollar per barrel crude oil in 2018) and show despite some limitation a similar course as crude oil prices. This means that virgin base oil prices on a general level are determined by and dependent on volatile crude oil prices, see Figure 14-1 below. Generally, high crude oil prices will result in high base oil prices and vice versa. European average prices for specific base oils of group I to III ranged from about 640 US $ per tonne (561 euro/tonne) to about 1 010 US $ per tonne (885 euro/tonne) for the year 2018 (Argus 2019). Prices vary considerably depending on the specific base oil group, the specific type of oil within a base oil group and whether export or domestic market are considered. On a more detailed level, prices of the specific base oil groups, e.g. group I, II or III, will depend on the specific supply and demand pattern of the individual base oil groups including short-term developments.

This can be seen by comparing the market trend of lower demand for base oil group I to higher demand for higher quality base oil groups (II and III) with the price developments in Europe for the year 2018 (Argus 2019). Group I base oil prices ended the year 2018 at lower levels than at the beginning of the year. Group II prices ended at a higher level than at the beginning of 2018, while group III prices ended slightly lower. Base oil group III prices had remained within a close range all year round as supply from outside the Europe increased. *"Group III prices rose sharply at the end of 2017 and beginning of 2018, before a series of Group III maintenance work began in March. Prices then tended lower after deliveries returned to normal after completion of maintenance."* (Argus 2019)

Figure 14-1 Historical crude oil prices, Europe Brent Spot Price FOB; Dollars per Barrel

Source: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=M; download 15.11.2019

The Table 14-1 below shows assumed costs for re-refining (and other recycling) of waste oil in the United States (CalRecycle 2013). Although the table presents old data from the United States, it is assumed that not the specific figures but rather some basic findings on re-refining of waste oil (see the two columns 'Re-refined', 'Low' and 'High') are transferable to the current situation in the EU. The subsequent Table 14-2 shows shares of costs for different purposes of waste oil management in Italy. The data is based on the overall waste oil management costs of CONOU of the year 2017 in Italy and generally confirms the data in some qualitative aspects of Table 14-1 (see Chapter 15.5 for more details on CONOU and the EPR scheme of Italy).

Production costs of re-refined base oil do not directly depend on crude oil prices. Re-refining operation costs, which are considered to be stable, make up for the highest share of the overall production cost of re-refined base oil. Considering stable operation costs and their high share of the total production costs, high crude oil prices resulting in high base oil prices are principally in support of re-refined base oil. In this context, a better understanding of the dependencies using the example of CONOU is helpful.

In Italy, companies placing lubricant oils on the market are required to pay a fee / contribution to CONOU for the management of the waste oil. In 2019, the contribution was 100 euro per tonne (120 euro/tonne in 2018) of lubricant oil placed on the market in the national territory. This contribution is variable and the amount decreases as the market price of the base oil increases and vice versa: a dynamic justified by the fact that the higher the price of the lubricant oil, the higher the price of re-refined base oil sold on the market by the re-refining companies, which are thus able to independently cover a larger share of their operating costs. Figure 14-2 shows the trend of the contributions payed for lubricant oils PoM compared to crude oil prices. It increased for example from a minimum of 50 euro/tonne in 2013 and 2014, when the price of the barrel crude oil was very high, to a value of 100 euro/tonne (about 9 euro cents per liter) in 2019.

The contribution is only paid when the lubricant oil is suitable to produce waste oil and therefore it is not paid for process oils (when lubricants are incorporated in other products, e.g. tires, plastics, etc.).

The main share of the contribution to CONOU is used to support the treatment activities of the re-refiners. Figure 14-3 shows the support for re-refining payed by CONOU (per tonne of produced re-refined base oil) compared to the prices of lubricant oil. As already explained above, support for re-refining is low when prices for lubricant oil are high and vice versa. For example, in 2014 110 euro/tonne of re-refined base oil was payed, in 2017 232 euro/tonne and in 2019 204 euro/tonne. Table 14-2 shows for the year 2017 how the contribution to CONOU (150 euro/tonne of lubricant oil PoM) was allocated to different uses. About 45% of the total contribution to CONOU was used to support re-refining (232 euro/tonne of re-refined base oil which corresponds to about 67 euro/tonne of lubricant oil PoM). About 20% of the total contribution was allocated to collection activities (collection, transport, storage and analysis) in 2017 (103 euro/tonne of re-refined base oil which corresponds to about 30 euro/tonne of lubricant oil PoM). Waste oil collection is free of charge for the generators of waste oil in Italy. In 2014 the amount of the contribution for the support of the waste oil collection and treatment activities together was about 29 euro/tonne of lubricant oil PoM while in 2019 the support was about 79 euro/tonne of lubricant oil PoM (2019: about 17% collection and 62% re-refining).

According to the assumptions in Table 14-1 (year 2013) collection and transport account for about 32% of the total production costs and operation and maintenance for about 46% (column re-refined, high). When considering the distribution of costs of CONOU in Table 14-2, it must be noted that not necessarily the real costs are given, but in particular when considering the re-refining a support payment takes place. The CONOU data mostly also takes into account the share of the contribution which is used for the fulfilment of the institutional purposes of CONOU. For example, about 5% of the total contribution from lubricant oil PoM is used for communication purposes.

Costs for the acquisition of the waste oil feedstock also present a high share of the overall production costs of re-refined base oil. The price of waste oil is considered the variable of the main influence on the viability of re-refined base oil production. In Figure 14-4, payments of collectors and re-refiners to waste oil generators (waste motor oil) in the US are compared with the prices of re-refined base oils. When crude oil prices collapsed in 2016 and thus also prices of lubricant oil and (re-refined) base oil, payments for waste oil had to be reduced too and even resulted in "negative" payments, i.e. charges for waste oil generators in the US. Generally, higher crude oil prices result in higher prices for waste oil and lower crude oil prices in lower waste oil prices.

When it comes to waste oil there is a competition between acquisition for treatment to fuel and re-refining to base oil. The selling price of waste oil is influenced by several factors such as the quality of the waste oil, the demand from re-refining, other treatment plants and cement industry, and the price of fuels. The demand for waste oil as a fuel clearly affects the price of feedstock for re-refining. Thus, when waste oil prices go up or down, re-refinery economics can be impacted substantially. (Infineum 2013)

Table 14-3 presents a comparison of the capital expenditures[56] of different waste oil treatment plants. The data shows that capital expenditures for re-refining of waste oil

[56] Capital expenditures are expenses of a company for acquiring, upgrading, and maintaining physical assets such as buildings, an industrial plant or equipment.

are at least two times higher than for treatment to fuels (MDO). Capital expenditures of plants for the treatment to heavy non-distilled fuels (RFO) are again significantly lower. For comparison, investment costs for a 120 000 tonnes re-refining plant in France (Osilub) are estimated to about 50 million euros (Infineum 2013). This corresponds to about 416 euros per tonne of capacity. Similar for operation and maintenance (O&M) in Table 14-1, costs are about two times higher for re-refining compared to treatment to fuels (MDO). Thus, re-refining of waste oils results in visibly higher treatment costs compared to the production of fuels.

Table 14-1 Cost assumptions for waste oil recycling operation costs; low and high costs in US $/Gallon

$/Gallon	RFO Low	MDO Low	Re-refined Low	RFO High	MDO High	Re-refined High
Collection	0.15	0.15	0.15	0.25	0.25	0.25
Transportation	0.1	0.1	0.1	0.2	0.2	0.2
O&M (fixed and variable)	0.1	0.2	0.4	0.15	0.35	0.65
Total Operating Cost	*0.35*	*0.45*	*0.65*	*0.6*	*0.8*	*1.1*
Feedstock	0.3	0.3	0.3	0.3	0.3	0.3
Total Production Cost	0.65	0.75	0.95	0.9	1.1	1.4
Euro/tonne	**RFO Low**	**MDO Low**	**Re-refined Low**	**RFO High**	**MDO High**	**Re-refined High**
Collection	35	35	35	58	58	58
Transportation	23	23	23	47	47	47
O&M (fixed and variable)	23	47	93	35	82	152
Total Operating Cost	82	105	152	140	187	257
Feedstock	70	70	70	70	70	70
Total Production Cost	152	175	222	210	257	327

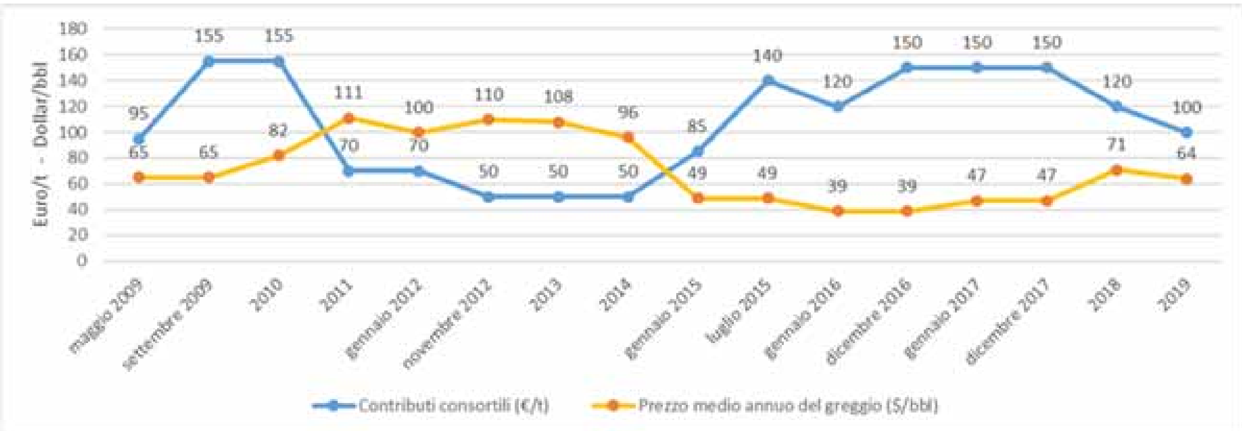
O&M: Operation and Maintenance
RFO: Recycled fuel oil facilities produce heavy non-distilled fuel
MDO: Marine distillate oil facilities produce light distilled fuel (marine diesel oil)
1.33 US $ = 1 euro
Source: CalRecycle 2013; figures in euro/tonne calculated by Oeko-Institut

Table 14-2 CONOU (Italy), share of costs of waste oil management, 2017

	cost share in %	Euro/tonne (PoM)	Euro/tonne (waste oil collected)	Euro/tonne (re-refined base oil)
Other managing costs	0.5%	1	2	3
Staff costs	3.6%	5	11	19
Corporate bodies	1.6%	2	5	8
Communication	4.6%	7	15	24
Storage and analysis	5.0%	8	16	26
Transportation	6.5%	10	21	34
Collection	8.3%	12	26	43
Compensation for regeneration	44.7%	67	142	232
Waste oil purchases	25.2%	38	80	131
Total	**100.0%**	**150**	**318**	**519**

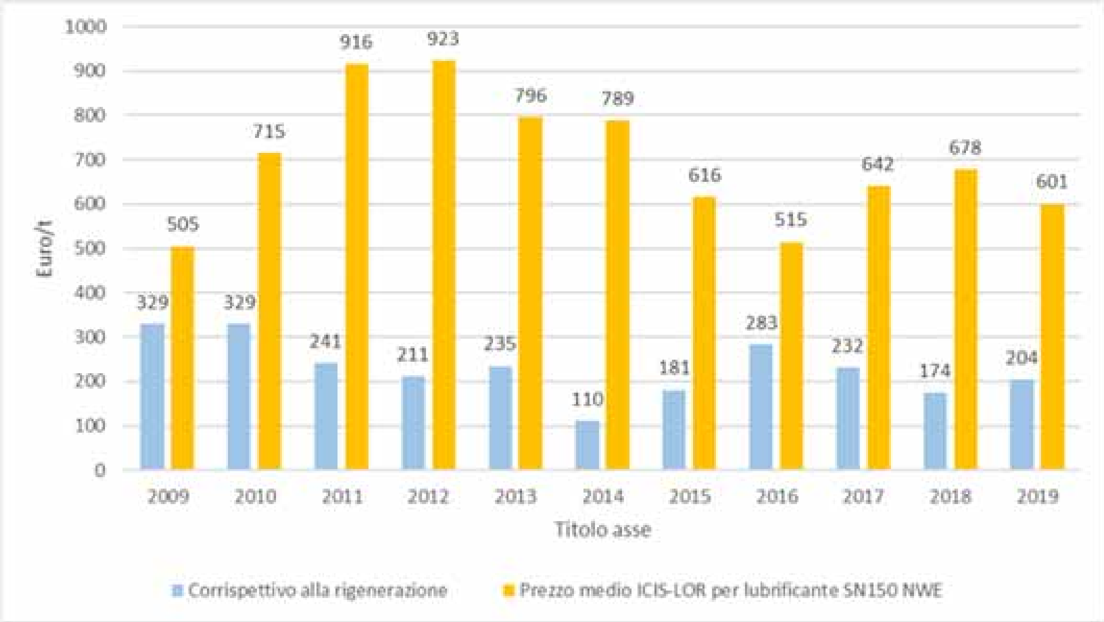
Source: CONOU 2017
Figures in euro/tonne calculated by Oeko-Institut based on CONOU collection/treatment data.
The assessment and possibilities for using the data, in particular on 'waste oil purchases', are limited due to methodological changes during 2017.

Figure 14-2 Evolution of the fees payed to CONOU compared to crude oil prices, Italy, years 2009 to 2019



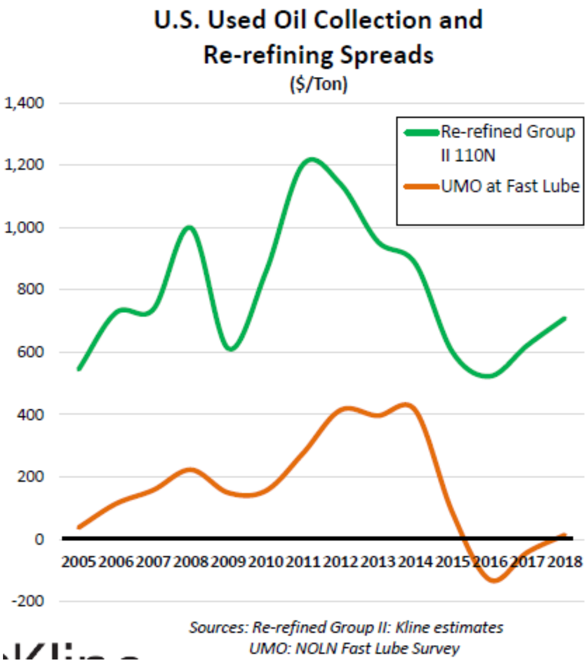
Contributi consortili= Consortium contributions
Prezzo medio annuo del greggio = Average annual price of crude oil
Source: Itelyum 2019

Figure 14-3 Evolution of the support for regeneration compared to the average price of SN150 lubricant oil



Corrispettivo alla rigenerazione = Compensation for regeneration
Prezzo medio ICIS-LOR per lubrificante SN150 NEW = Average price ICIS-LOR for lubricant SN150 NEW
Source: Itelyum 2019

Figure 14-4 Evolution of the waste oil prices (UMO= used motor oil) compared to the prices of re-refined base oil Group II in the US; US $/tonne, years 2005 to 2018



Source: Kline 2019

Table 14-3 Assumed capital expenditures for waste oil treatment, United States

	RFO Low	MDO Low	Re-refined Low	RFO High	MDO High	Re-refined High
$/Gallon of capacity	0.15	0.85	2.0	0.5	1.45	3.0
Euro/tonne of capacity	35	199	467	117	339	701

Source: CalRecycle 2013; figures in Euro/tonne calculated by Oeko-Institut; 1.33 US $ = 1 Euro

Given the high costs of re-refining, the management system of waste oils in Italy within the framework of the extended producer responsibility and in compliance with the "polluter pays principle" provides an incentive for re-refining companies (financial support for re-refining). Italy clearly supports the priority of re-refining above energy recovery and almost 100% of the waste oil is sent for regeneration in re-refineries.

In the UK, there appears to be no clear priority for regeneration of waste oil over treatment to fuel. End-of-waste (EoW) criteria for wastes oil have been developed for use as a fuel. Existing re-refineries appear to have free capacity but still about two thirds of all waste oil undergoes treatment to fuel. Therefore, the UK is seen as an example where re-refining to base oil is losing in competition against treatment to fuel as there are no measures (no financial incentives or legal measures) supporting the priority of re-refining given in the waste hierarchy.

Overall, the competitiveness of re-refined base oil depends on many factors such as demand for base oil, quality of the base oil, production costs and the price of crude oil. However, in particular with regard to competition between re-refining and the use as a fuel and in times of low crude oil prices, financial incentives are helpful to overcome high costs of re-refining and to support the implementation of the waste hierarchy.

15 Best practices

The waste hierarchy gives priority to the regeneration of waste oils over energy recovery and in fact about 61% of the waste oil collected in the EU-28 is used as a feedstock to re-refineries resulting in regenerated base oils. Despite the requirements of the waste hierarchy its implementation differs between the MS, where about 24% of total waste oil was treated to produce fuels and about 11% was burned for energy recovery in cement, lime, steel and power plants.

In individual Member States specific policies are adapted to improve the collection and recycling of waste oils. EPR (extended producer responsibility) schemes for waste oils exist according to (EC-EPR 2014) in ten MS. Similar (voluntary) systems exist also in most other MS (EC-WFD 2015), see Table 17-1.

Best practice in relation to transparency and availability of data and information on waste oil management is not the focus of this study. However, EPR schemes and organisations involved in collection systems often provide detailed reports[57] on their activities, e.g. in Belgium, Italy and Portugal.

Guidelines for the environmentally-friendly management of waste oils were developed in (UNEP 2015). Eight steps are described for establishing the regeneration of waste oils in a country:

- *“Step 1: Appointment of Ministry/Department responsible for used oil management and performance of a feasibility study addressing environmental, technical and economic aspects*
- *Step 2: Initiate dialogue, awareness and training campaign and partnership with stakeholders*
- *Step 3: Pass a law on used oil management and financial plan*
- *Step 4: Create a database of consumption of new lubricant oils*
- *Step 5: Create a database of recovered used oil, ratios and objectives*
- *Step 6: Initiate used oil collection logistics*
- *Step 7: Establish used oil transfer centers*
- *Step 8: Establish used oil regeneration / re-refining plants”* (UNEP 2015)

In the following sections best practice cases in MS and different areas, e.g. collection schemes, target setting or information systems, are presented. The best practice cases provide only a selection of MS, similar examples can also be found in other MS. Subsequently, the results are summarised and possible conclusions are discussed.

15.1 Belgium

Belgium provides a good practice example for the communication and information about waste oil management. Generally, two separate target groups, households and professionals, are addressed (Belgium 2017).
Communication with households in the years 2016 and 2017:

[57] Belgium: https://valorlub.be/fr/valorlub

Italy: http://www.conou.it/it/rapporto-di-sostenibilita/

Portugal: https://www.sogilub.pt/quem-somos/relatorios/

- national specialised media (2016 only);
- actions at points of sale: provision of leaflets, "wobblers";
- internet: "overlayers" with banners. The actions focused on websites dedicated to second-hand cars and motorcycles;
- campaign via the radio media.

Communication with professional users is mainly through specialised magazines, communication channels of professional federations and trade fairs and exhibitions. Based on the results of a targeted analysis carried out by a specialised office, it was found that radio media has the greatest potential to reach professional users, while remaining affordable. Therefore, the 2018 communication shall target the professional public via this channel. Since 2012, awareness campaigns on the use of biodegradable oils for users of chainsaws and formwork release oils have been conducted.

Belgium has introduced objectives for waste oil management and for lubricants (Belgium 2017):

- Collection of at least 90% of the quantities of potentially collectable waste oils (taking into account losses during use);
- Treatment of collected waste oils in accordance with national, federal and European legislation; at least 60% of waste oils must be regenerated or treated by material recovery (e.g. production of standard fuels).
- Promotion of the use of biodegradable oils for applications (where applicable and where lubricants are lost during use).

In Belgium between 78% and 99% (depending on data source and year) of the collectable waste oils were collected; see Table 27-4. Furthermore, about 60% of the lubricant oil placed on the market was collected (2017). The share of the collected waste oils which was re-refined (export for re-refining) accounts for about 84% to 96%.

Overall, Belgium is one of the MS with the highest collection rates and the highest regeneration rates.

15.2 Denmark

In Denmark, waste oils suitable for re-refining are collected free of charge by two organisations (voluntary PRO of lubricant producers and importers). The collection system is financed by a levy (advanced disposal fee) on new gear, engine and hydraulic oils sold (excluding cutting, drilling and marine lubricants). Waste oil producers can register for the collection scheme and do not have to pay for collection. The funds collected through the levy are passed to an Environmental Pool fund used to support the free collection of re-refinable waste oils. Financial support for the collectors is paid based on the recovered oil ultimately re-refined. It is paid for the total volume of both the regenerated base oils and fuel oils produced (re-refinable oil collected, after solids and water are removed). For waste oils not used as a feedstock for re-refining (waste oils contaminated with metals or with high volumes of water, e.g. bilge oils) instead market rates have to be paid for their disposal. (EC-WFD 2015, Ademe 2010, OakdeneHollins 2009)

Regeneration of waste oil has priority over fuel use. This was established in Denmark via fiscal and regulatory changes and has been achieved by restricting competition for waste oil collection to two companies. One of them operates the country’s sole re-refinery. (OakdeneHollins 2009)

Denmark has set a priority of regeneration for its waste oil management, and reviews applications for waste exports to ensure that waste oils can be regenerated in this way. By processing applications for waste exports, Denmark ensures that waste oil that is suitable for regeneration is exported for processing in this way. (EC-WFD 2018).

The Danish regulations do not define any quantified objectives for waste oil recycling. However, a voluntary target of regenerating 75% of the waste oils collected was set in the national waste disposal strategy 2005-2008. (Ademe 2010)

15.3 Finland

Finland provides a good practice example for measures to prevent mixing of waste oils with different properties (EC-WFD 2015). The measure specifies that only waste oils that are properly separated are collected free of charge. The threat of a charge in case of not properly separating provides a strong incentive against mixing of waste oils of different types. The following instructions by the waste oil collector apply to the separate collection of different waste oil types:

- black oils (motor oils or transmission oils; input to re-refineries for base oil production for lubricant manufacturers);
- bright oils (hydraulic oils, gear oils, compressor oils, circulation lubrication oils and turbine oils; e.g. used for the production chain saw oils) which do not contain PCBs; and
- vegetable oils.

In Finland, producers and importers of lubricant oils also have to pay a fee on lubricant oils and greases. The resulting funds are used for collection, transport, storage and treatment of waste oils. Furthermore, a part of the money is also used for the cleaning up of oil-contaminated soil and groundwater.

Finland has not set a legislative collection or recycling target. However, the contract with the PRO scheme requires a yearly collection of a minimum amount of 20 000 tonnes of waste oil (calculated as < 10 % of water). Most of it shall be regenerated to new oil products. (EC-WFD 2015)

According to (GEIR 2019) about 22 000 tonnes of waste oil is collected per year which corresponds to roughly 50% of the collectable waste oil.

15.4 Greece

Greece has adopted legislative measures for waste oil management. These measures essentially comprise the following aspects:

- Establishment of an EPR system and related PRO scheme
- Quantitative targets for waste oil
- Priority list for waste oil treatment
- Prohibition of mixing waste oils

Greece has introduced an EPR system (Decree 82/2004), namely the producer’s obligation to organise oil collection, transport, storage and treatment, giving priority to waste oil regeneration. Oils importers and producers are obliged to organise systems in which they pay a certain contribution in proportion to the quantities they put in the market. (EC-WFD 2015)

For those products for which EPR principle applies, such as lubricant oils, a National Producers’ Registry (N.P.R.) was set up. Waste oils are subject to separate collection, recycling and recovery. Participation in the N.P.R. is compulsory for all parties placing the relevant products on the national market (producers, incl. importers). These parties are obliged to organize or participate in PRO Schemes. (MS survey 2019)

The PRO system included in 2010 about 170 (160 in 2016) affiliated companies (50 are producers of lubricant oil, 44 importers of cars and 76 lubricants importers) theoretically covering 95% of the total market for lubricant oils. Furthermore, the system collaborates with the following major lubricant consumers: public power corporation, armed forces and local authorities. The PRO system has contracted with 40 licensed collectors and includes about 13 500 collection points, 8 collection centres. The waste oils are treated in 8 regeneration facilities. (HRA 2019) (MS survey 2019)

Quantitative targets for waste oil are defined in Decree 82/2004 (HRA 2019):

- at least 70% by weight of all waste lubricant oils (collectable waste oil) must be collected and
- out of these at least 80% by weight must be regenerated.

The national collection target also takes into account marine oils (for the domestic market). According to (MS survey 2019) the collection target would have been achieved if marine oils/bilge oils were not included.

Following the provisions of Decree 82/2004, an explicit priority concerning the regeneration of waste oils has been set and only if this is not feasible, technically, economically and organizationally, may the waste oils be disposed of in incineration. The following priority list applies:

- (a) Regeneration;
- (b) Energy recovery, when regeneration is not technically or organizationally possible;
- (c) In cases that neither regeneration nor energy recovery are possible, environmentally sound disposal or controlled storage.

In addition, export of waste oil in order to be disposed of in incineration or co-incineration facilities is prohibited in cases where regeneration in Greece is technically feasible. (MS survey 2019)

Based on the data of (MS survey 2019) about 68% (2014 and 2015) to 70% (2016) of the collectable waste oils were collected in Greece (incl. domestic marine oils). Excluding domestic marine oils results in a collection of 74% of the collectable waste oils.

The share of the collected waste oils which was re-refined accounts for about 100%. Only some minor amounts of waste oil were exported for disposal (D10). Export includes solely oils containing PCBs/PCTs (less than 0.2%). (GEIR 2019, MS survey 2019)

The waste oil management legislation explicitly includes the separate collection of waste oils and prohibits the mixing of waste oils with other waste or materials. To prevent the contamination of waste oil, spot checks and sample analysis are foreseen in collection centres and in regeneration facilities in case of signs of contamination of waste oils by other substances. Furthermore, waste oil producers have to declare that the waste oils have not been mixed with foreign substances in their accompanying identification documents (transport to regeneration facilities). (EC-WFD 2015)

15.4.1 Waste oil collection system and transfer centres

In Greece as part of the EPR scheme a comprehensive collection system has been developed which consists of waste oil collection points, transfer stations for the temporal storage of the collected waste oil, chemical laboratories for the testing of the collected waste oil and a real-time monitoring system of the collection. (LIFE 2005)

The transfer stations include weighbridges and storage tanks from where the waste oils are transferred to re-refining facilities. The monitoring system continuously transmits data from transfer stations and collection trucks to a data centre.

Environmental benefits are (WFD 2016):

- Sustainable management and collection of waste oils, and a continual increase of the collected waste oils aiming to reach the 80% of the collectable waste oil quantities;
- Respective decrease of the quantities of illegally disposed waste oil (dumping, burning etc.);
- Minimisation of the fuels used in the collection truck fleet as a result of an optimum routing of the fleet (minimisation of travelled km per collected waste oil tonne).

15.5 Italy

In Italy, an EPR scheme for waste oil management is in place. CONOU (Consorzio Nazionale per la Gestione, Raccolta e Trattamento degli Oli Minerali Usati) is the national consortium for the management, collection and treatment of mineral waste oils. CONOU is a private legal entity operating in accordance with the EU principles of the Extended Producer Responsibility (EPR). The main tasks of CONOU are:

- to promote the public awareness on the topics related to the correct management of waste oils;
- to ensure and promote waste oils collection throughout the national territory;
- to select the waste oils collected for their correct disposal;
- to ensure that the waste oils collected are sent to the most appropriate treatment and primarily to re-refining for the production of base oils, in accordance with the EU principle of the so called "waste hierarchy";
- to promote waste oils re-refining according to the market conditions;
- to pursue and encourage the study, experimentation and realization of new treatment processes for waste oil;
- to record and process all the technical data concerning waste oils collection and disposal (traceability).

CONOU does not perform the aforesaid tasks directly. CONOU must ensure that qualified operators (basically collectors and re-refiners) do that. In particular, collecting companies (about 70) sign a service agreement with CONOU in which they commit themselves, in a specific area, to collecting the waste oils also in the most disadvantaged locations and without charging any fee to the waste oil producers. Collectors are obliged to carry out free collection provided that the quantity to be collected is at least 200 kg. Apart from this obligation, collectors are free to collect the waste oils throughout the national territory respecting the clause of the free collecting service.

The private operators are authorised by the competent authorities to collect waste oils from holders (industry, service stations, vehicle repair shops, recycling banks, etc.). Once transferred to the consortium's depots, waste oils are analysed to identify their properties and to decide on the correct treatment of the waste oils. In order to cope with its activity of analysis and control, CONOU commissioned 7 920 control analysis in 2018.

CONOU is governed by a Board of Directors in which the majority of the members represents the companies producing lubricant oils. These companies are obliged to finance CONOU's activities in order to achieve the aforementioned goals. There are currently eight members of t he Board representing the aforesaid. Besides, according to the principle of the shared responsibility of the supply chain operators, two board members in representation of the collecting companies and two board members in representation of the re-refining companies are also present. The Board is completed by the President and the Vice President, who can be classified as "independent". Currently President and Vice President are former managers of important companies operating in the lubricants production and marketing.

The Board of Directors also decides the contribution/fee the companies which put lubricants on the market are required to pay to the Consortium so that it can fulfil the obligations provided by the by-laws of CONOU. For more details on the financial aspects please refer to Chapter 14.

(Itelyum 2019, CONOU 2019, EC-WFD 2015)

In Italy, priority is given to the regeneration of waste oils and the prohibition of transboundary shipment of waste oils to incineration or co-incineration facilities is implemented. The following priority list applies (EC-WFD 2015):

- (a) regeneration aimed at the production of lubricant bases;
- (b) alternatively, but still in accordance with the priority order, if regeneration is technically unfeasible and not economically viable, combustion of waste oils;
- (c) as a last resort, if the treatment processes referred to in subparagraphs (a) and (b) above are not technically feasible due to the composition of the waste oils, through the disposal operations.

In Italy, about 93% of the collectable waste oil was collected in 2017 (MS survey 2019). The collection rate based on the actually collected waste oils and the amounts of lubricant oil placed on the market, about 400 000 tonnes, was 46.7% (Itelyum 2019a) in 2018 (2017, 43% (MS survey 2019) or 41% (own calculation based on CONOU 2017)). Up to 100% of the collected waste oil is regenerated to produce re-refined base oil (Conou 2017, MS survey 2019). Only small amounts of waste oil go to energy recovery or incineration (about 1% in 2017). The yield in base oils of the re-refining plants was 65% in 2018.

15.6 Portugal

In Portugal, an EPR scheme for waste oil management is in place where waste oil is collected free of charge. In the answer to the Member State's questionnaire the system is described as follows (MS survey 2019):

"Portugal has introduced in the legislation the extended producer responsibility (EPR) for waste oils in 2003. Thus the producers that put oils on the market are responsible for the waste generated after the oil has been used by consumers. Since there is no authorized individual system, all the producers must shift their waste management responsibilities to the licensed collective system, since 2005, SOGILUB – Sociedade de gestão integrada de óleos lubrificantes Usados, Lda. This shifting of responsibility is both physical and economical so SOGILUB is obliged to collect waste oils in the waste oils producer's facilities with no costs and it is responsible for waste oils treatment and final destination. In order to guarantee the accomplishment of the waste hierarchy the license of the collective system reflects the national targets by setting targets of regeneration, recycling and recovery as well as collection."

Portugal has developed the following targets for waste oil management (see Decree Law No 153/2003 of 11 July 2003, as amended by Decree Law No 73/2011 of 17 June 2011)(EC-WFD 2015):

- 85% collection of waste oils generated annually;
- 75% recycling of waste oils collected and 50% regeneration of waste oils collected where these oils meet the required technical specifications.

Based on the data of (MS survey 2019) between 79% and 92% of the collectable waste oils were collected in Portugal (years 2014 to 2017). The share of the collected waste oils which was re-refined accounted for 69% to 81% and the remaining share of 19% to 31% was recycled (SIGOU 2018) or treated to fuel (GEIR 2019)[58].

Portugal has also implemented monetary incentives for lubricant producers in 2018 in order to encourage the use of environmentally-friendly lubricants:

"…the Administration approved a matrix of bonus to deduct on fee paid to the collective system by producers that place on the market environmental-friendly oils. The matrix considers four criteria: lifespan of the oil, oil manufactured with renewable materials, oil incorporating regenerated bases and biodegradability of lubricating oils placed on the market." (MS survey 2019)

Furthermore, Portugal has developed measures for better information on waste oil management. This includes following aspects (EC-WFD 2015):

- a helpline to provide clarifications;
- an institutional newsletter presenting scientific and technical information and publishing developments in legislation and other issues on the waste management agenda;
- awareness raising and training with producers of waste oils and waste management operators to give them the capability to prevent the mixing of waste oils with different characteristics and the mixing of waste oils with other waste or other materials.

15.7 Spain

In Spain, an EPR system for the management of waste oils is in place. Manufacturers of lubricant oils are obliged to ensure the management of the waste oil generated and have to bear the total cost of the waste oil management. All companies placing lubricants on the market have to pay a fee depending on the volume. This applies also for exports of lubricants; fees have to be paid but are refunded as treatment does not take place in Spain. SIGAUS is the organisation in charge of the waste oil management is Spain. About 130 authorized companies are active in the collection, transport, storage, analysis, pre-treatment and final treatment of waste oil. More than 60 000 collection points exist all over Spain and ensure waste oil collection regardless of the volume to be collected and the distance to transfer or management centres. Waste oils except from emulsions are mixed at origin to avoid costs and environmental impacts from logistics as they are all treated together in the end. (EC-WFD 2015, UNEP 2015, MS survey 2019)

In Spain, the treatment of waste oil through regeneration shall have priority in the management of waste oils, which, in all cases, shall be carried out in this order of preference: regeneration, other forms of recycling and energy recovery. Moreover, the Spanish law allows for restricting exports of waste oil from national territory to

[58] The information is not in agreement. While GEIR reports treatment to fuel, SIGOU reports recycling (not energy recovering, which is addressed separately).

incineration or co-incineration facilities, in order to give priority to regeneration. (EC-WFD 2015)

Spain has developed legal objectives for waste oil management which include (UNEP 2015):

- recovering more than 95% of the waste oils;
- valorising 100% of them;
- regenerating more than 65% of total waste oil.

Waste oils that are not regenerated are subjected to physical-chemical treatment to obtain a fuel similar to fuel oil that can be used in power plants, cement plants, paper mills or other industrial facilities.

In Spain, between 83% (2016) and 96% (2014) of the collectable waste oil was collected in the year 2014 to 2017. Between 69% and 78% of the collected waste oil is regenerated to produce re-refined base oil and between 21% and 31% was treated for energy recovery. The disposal of waste oil is forbidden in Spain. Exception is granted for PCB-containing oil, for which disposal is mandatory. (MS survey 2019)

As part of a prevention programme, SIGAUS encourages lubricant producers to implement measures related to lubricant applications and best practices. The aim is for example reducing the generation of waste oil or increasing the life cycle length. As part of the communication, SIGAUS strategy addresses relevant stakeholders (lubricant producers, waste oil management companies, waste oil producers and the public administration) and informs them about their activities and environmental benefits of waste oil management. Furthermore, awareness campaigns for the general public are carried out (website www.sigaus.es, social networks, publications and media campaigns). (UNEP 2015)

15.8 United Kingdom

An example of good practice regarding information comes from the UK (for other aspects which cannot be considered good practice see Chapter 14). The Oil Care Campaign is a joint initiative between the UK environmental regulators, trade and professional bodies and industry. For detailed information please refer to www.oilcare.org.uk.

The campaign, among other things, aims to "*To develop and provide guidance for domestic, commercial and industrial users on the safe handling, storage and recovery of oils, to reduce the environmental impact of spills from poor practices in the storage, use and disposal of oils.*"

The campaign provides information on the collection of waste oil. This is done on a separate website (www.oilbankline.org.uk) where users can find information on their nearest waste oil disposal site.

Furthermore the campaign supplies "*oil tank stickers for domestic, industrial and waste oil tanks. The stickers provide advice on oil storage, with a reminder to have oil storage tanks checked annually to ensure they're in suitable condition to store your oil and what to do if there's an oil spill.*"

16 End-of-waste criteria

Uncertainty over the point at which waste has been fully recovered and ceases to be waste may inhibit the development and marketing of materials produced from waste oil. With regard to the waste hierarchy, it is of interest whether the end-of-waste criteria address or are targeted towards a particular type of product. Therefore, the end-of-waste criteria for waste oils were analysed for all MS to assess whether the products addressed by the criteria could constitute a driver towards a specific waste treatment option (namely, production of fuel versus regeneration to base oil).

Table 16-1 presents an overview on end-of-waste criteria of EU Member States. Overall, information on end-of-waste criteria for waste oil was identified in seven MS. In all MS but France (and partially the Czech Republic) the end-of-waste criteria address the use as fuel. To assess whether the end-of-waste criteria might have a specific effect on the treatment of waste oil in a particular MS the shares of treatment to fuel, energy recovery and re-refining are listed in Table 16-1 for comparison. At least four of the seven MS that have EoW associated to fuel produced from waste oil have a high share of waste oil being treated to fuel or energy recovery. In particular in Croatia, Estonia and the UK more than about two thirds (and up to 100%) of waste oil is treated for use as fuel or directed to energy recovery. At the same time, comparable small shares of waste oil are re-refined in these MS. The average share of re-refining in these seven MS is about 39% compared to about 51% in average of all other MS where no end-of-waste criteria were identified.

In Belgium re-refining of waste oil (84% to 96%) is clearly favoured over all other treatment options. However, Belgium also has end-of-waste criteria for the use as fuel (only 5% of the collected waste oil is treated to fuel). France has an end-of-waste criterion for recycling of waste oil to bitumen plasticizer in the manufacture of roofing waterproofing membranes and also a comparably high share of re-refining (69%).

The analysis may indicate that MS that have developed specific end-of-waste criteria for waste oils tend to favour treatment to fuel rather than countries without them. This may indicate that EoW criteria defining fuel products derived from waste oil are a negative driver towards promoting regeneration to base oils. However, since there are also clear contrary examples with Belgium, for example, (and it remains unclear whether for other MS there really are no end-of-waste criteria for waste oil or simply these could not be identified) it is not possible to make a clear assessment regarding a potential dependency between end-of-waste criteria and waste treatment options.

Table 16-1 End-of-waste criteria for waste oils in the EU by MS; treatment to fuel/energy recovery for comparison

MS	EoW	Further use for	Source	Treat-ment to fuel	Energy reco-very	Re-refi-ning
BE	Yes	a) glasshouse horticulture sector: use as fuel to replace heavy fuel oil or as a substitute for gas/diesel oil b) inland water transport: as blending agent for fuels; with S content < 0,1% as fuel c) maritime transport: blending agent or as substitute for distillation of maritime fuels	EoW criteria voor afgewerkte olie, 2010	5%		95%
CZ	Yes	Czech standards for oil quality can be used as end-of-waste criteria. According to current legislation in field of waste management the products based on waste oils (mainly heating oils, regenerated oils) cease to be waste after treatment in waste treatment facility, which has permitting authority on the end-of-waste process. Exact end-of-waste conditions are established in the permit and operating conditions of the facility and approved by regional authority.	MS survey 2019	13%	44%	9%
EE	Yes	a) additive in the production of liquid fuels (§9)	Draft 2018_662_EE_EN		100%	0%
ES	Yes	a) use of processed waste oil as fuel b) recovered fuel oil from the treatment of MARPOL type c waste for use as fuel on ships	• Orden APM/205/2018 • Orden APM/206/2018	30%		70%
FR	Yes	a) bitumen plasticizer in the manufacture of roofing waterproofing membranes	Arrête du 17 juillet 2017, Version consolidée 17.10.2019	4%	23%	69%
HR	Yes	The cease of waste status is regulated by the Ordinance on by-products and cease of waste status (OG 117/14). Special criteria for cease of status of waste for fuel from waste oil is set out in Annex VII (3.) to the Ordinance OG 117/14.	MS survey 2019	29%	71%	0%
UK	Yes	a) Processed Fuel Oil (PFO)	UK 220090473 EN PFO	67%		33%

Source: share of treatment options based on GEIR 2019

17 Overview and conclusions

In the individual examples of the MS in the previous chapters, collection systems and specific targets were presented as best practices. In the following, factors influencing the collection rates of waste oil and the share of waste oil treated in re-refineries is analysed. The question is whether there is a correlation between these measures and higher collection rates and higher re-refining rates.

Table 17-1 provides an overview on the MS that have established EPR schemes (or PRO, polluter-pays-principle or similar/voluntary systems) for the collection of waste oil. Furthermore, existing targets for collection rates and for regeneration of waste oil are also included in the table. As several MS did not take part in the MS survey or were not included in other literature[59], it remains unclear whether for these there is really no EPR and no targets or only information gaps.

[59] (EC-WFD 2015) presents a main source of information and covers the period 2010 to 2012. Potential changes in the recent years cannot be ruled out.

Table 17-1 EPR schemes and collection / regeneration targets by MS; collection rates and shares of regeneration for comparison (2017)

MS	EPR	Targets and measures	Collect. Rate, collectable	Collect. Rate, consumption	Re-refin-ing	Energy recovery	Ex-port restriction
BE	EPR	At least 90% collection of generated (collectable) waste oil (Belgium 2017) At least 60% of waste oils must be regenerated or treated by material recovery (Belgium 2017) Flanders: 90% collection target and a treatment target. Brussels-Capital-Region (BCR): regeneration or other re-use min. 60% (R9) and main use as fuel or other means of generating energy max. 40% (R1) (EC-WFD 2018) For both Flanders and BCR: 85% treatment by means of regeneration, re-refining or other reuse for certain waste oils; the remaining part is incinerated with energy recovery if possible; exported quantity of waste oils is monitored to ensure compliance with these targets (EC-WFD 2018)	97%	58%	95%	5%	yes
BG	EPR	Persons placing oils on the market are responsible for the recovery of at least 40% of the amount of oil placed on the market in the current year (EC-WFD 2018) No other (apart from 40% recovery, see above) recycling or collection targets (BG-NWMP 2014) No restriction of transboundary shipment for co/incineration (EC-WFD 2018)	59%	28%	80%	20%	no
CZ	EPR	No restriction of transboundary shipment of oils with the objective of expediting regeneration (EC-WFD 2018)	96%	50%	9%	58%	no
DK	Voluntary PRO scheme	Voluntary target to regenerate 75% of waste oils collected (Ademe 2010) DK reviews applications for waste exports to ensure that waste oils can be regenerated (EC-WFD 2018)	73%	36%	100%	0%	yes
DE	EPR	The transboundary shipment of waste oils is allowed in accordance with the Basel Convention and European Regulation on Shipments of Waste (EC-WFD 2018)	100%	43%	62%	30%	no
EE	none	No restrictions on transboundary shipment of waste oils (EC-WFD 2018) Priority on the regeneration of waste oils if this is technically feasible, economically viable and if other recovery operations do not ensure a better overall environmental result (EC-WFD 2018)	57%	27%	0%	100 %	no

MS	EPR	Targets and measures	Collect. Rate, collectable	Collect. Rate, consumption	Re-refin-ing	Energy recovery	Ex-port restriction
IE	Collection scheme	No requirements for regeneration of waste oils, nor restrictions on transboundary shipment of waste oils from its territories to co/incineration. (EC-WFD 2018)	100%	49%	0%	100 %	no
EL	EPR / PRO	At least 70% by weight of all waste lubricant oils must be collected and of these at least 80% by weight must be regenerated (HRA 2019) Export not allowed to co/incineration abroad provided regeneration is technically feasible within the country (EC-WFD 2018)	80%	45%	100%	0%	yes
ES	EPR / PRO	95% recovering of the used industrial waste oils 65% regeneration of total used industrial waste oil To give priority to regeneration, authorities may restrict exports to co/incineration (EC-FWD 2015)	78%	38%	70%	30%	yes
FR	voluntary PRO scheme	No requirements for the regeneration of waste oils (EC-WFD 2018) No restrictions on the transboundary shipment of waste oils to co/incineration (EC-WFD 2018)	73%	34%	69%	28%	no
HR	EPR	"[…] if the regeneration of waste oils is technically feasible and economically viable in the territory of Croatia, any export of waste oils for the purpose of their treatment by incineration or co-incineration shall be prohibited" (EC-WFD 2018)	93%	45%	0%	100 %	no
IT	EPR	IT gives priority to regeneration and exercises its right to limit export to co/incineration (EC-WFD 2018)	100%	42%	99%	1%	yes
CY	Collection scheme	No regeneration and no transboundary shipment of waste oils. Waste oils are refined to remove heavy metals and other ingredients in licensed treatment facilities producing a secondary type of fuel similar to LFO (light fuel oil) which is used in cement kilns. (EC-WFD 2018)	100%	47%	0%	100 %	no
LV	none	No waste oils are regenerated in LV and export of waste oils is allowed with no restrictions. (EC-WFD 2018)	100%	43%	0%	100 %	no
LT	PRO	"..., with the approval of a new 2014-2020 National Waste Management Plan in 2014, ..., oil producers and importers are no longer bound by any recycling targets." (EC-WFD 2018) No restriction of transboundary shipment of waste oils (EC-WFD 2018)	83%	43%	80%	20%	no

MS	EPR	Targets and measures	Collect. Rate, collectable	Collect. Rate, consumption	Re-refin-ing	Energy recovery	Ex-port restriction
LU	Collection scheme	Regeneration as the primary method of treating waste oils (EC-WFD 2018) In order to give priority to regeneration, the competent authority may lift objections to cross border transfers for co/incineration so that waste oil can be regenerated. (EC-WFD 2018)	100%	60%	100%	0%	yes
HU	none	Decree No. 4 of 23rd February 2001 stipulates that waste oils should be regarded as energy sources (EC-WFD 2018) No criteria regarding transboundary shipment of waste oils (EC-WFD 2018) Certain mineral oil products are products subject to product fee. No product fee is payable when this product is produced from waste oil. Reimbursement of paid product fees can be requested in case of material recovery of the mineral oil product --> supports material recovery of waste oils A decree stipulates that waste oils should be regarded as energy sources, provided that their incineration would not present risks to the environment. (EC-WFD 2018)	48%	17%	0%	52%	no
MT	none	MT exports all waste oils for regeneration. Authority can restrict shipment from its territories to co/incineration in order to give priority to regeneration (EC-WFD 2018)	100%	54%	0%*	0%	yes
NL	none	A waste oil sector plan imposes requirements on the import and export of waste oils to allow their regeneration.	96%	47%	94%	6%	yes
AT	none	Austria prioritises regeneration but does not restrict exports.	92%	47%	71%	29%	no
PL	EPR	Level of recovery at least 50% and recycling understood as regeneration of at least 35% (PL-NWMP 2016) If waste oils were to be exported to co/incineration, a protest against such shipment in order to give priority to regeneration would result (EC-WFD 2015)	75%	37%	52%	48%	yes
PT	EPR	85% collection of waste oils generated annually; 75% recycling of waste oils collected; 50% regeneration of waste oils collected where these oils meet the requisite technical specifications (EC-WFD 2018) SOGILUB has set targets in its permit for increasing the regeneration rate (80% in 2019) and a recycling target of 100% as from 2018 (90% in 2015).(EC-WFD 2018) Restrictions on transfers of waste for disposal from Portugal (EC-WFD 2018)	93%	38%	77%	23%	yes

MS	EPR	Targets and measures	Collect. Rate, collectable	Collect. Rate, consumption	Re-refin-ing	Energy recovery	Ex-port restriction
RO	EPR	Setting of annual waste oil management obligations for business operators that sell oils on domestic market: 40% of the amount of oil placed on the market in 2011, 60% in 2012; 80% as of 2013 (EC-WFD 2015; RO-Lege 167/2010 Annex 4) Authority can restrict shipment from its territories to co/incineration facilities in order to give priority to regeneration (EC-WFD 2018)	38%	19%	17%	83%	yes
SI	Collection system	Regeneration of waste oils does not have priority over co-incineration or incineration (EC-WFD 2018) No restrictions on transboundary shipments, only that priority to disposal of waste in SI should be given over disposal of waste abroad (EC-WFD 2018)	100%	47%	0%	100 %	no
SK	none	50% material recovery and 10% energy recovery for 2018 (SK-WMP 2015) 60% material recovery and 15% energy recovery for 2020 (SK-WMP 2015) No additional restrictions to export of waste oils to co/incineration (EC-WFD 2018)	58%	28%	0%	100 %	no
FI	EPR/PRO	PRO contract requires annual collection of min. 20 000 t of waste oil (EC-WFD 2018) No additional restrictions for export of waste oil to energy recovery (EC-WFD 2018)	73%	36%	91%	9%	no
SE	none	No restrictions for use as fuel in cement and lime kilns.	89%	44%	50%	50%	no
UK	voluntary collection scheme	No requirements for waste oils to be regenerated in the UK; some export for incineration is allowed where it is classed as for recovery, but export for incineration classed as for disposal is prohibited. (EC-WFD 2018)	65%	32%	33%	67%	no

* According to GEIR 2019 waste oil is exported not for re-refining but ‘other’; according to EC-WFD 2018 all waste oil is exported for regeneration
Source:
EPR: EC-WFD 2018, EC-WFD 2015, EC-EPR 2014, Ademe 2015 (France), MS survey 2019 (Portugal)
Collection rates and share of regeneration based on GEIR 2019

Figure 17-1 presents collection rates of waste oil by MS. Both different methods for the calculation of the collection rates (see Chapter 8), collection based on the collectable waste oil (‘collection rate (collectable)’) and collection based on the lubricant oils PoM (‘collection rate (consumption)’), are included in the figure. The MS with the highest collection rates are listed on the left. MS are sorted based on ‘collection rate (collectable)’.

In order to identify potential dependencies of the collection rates additional parameters are included in the figure: EPR schemes (‘EPR yes’), setting of collection targets (‘collection target’) and availability of re-refineries (‘Re-refiner yes’) in the country.

One or the other type of collection system and **EPR scheme** exist in almost all MS. Significant differences between the systems cannot, however, be identified on the basis of the evaluated sources. Therefore, a high collection rate cannot be correlated with the simple existence of an EPR scheme. The extent to which the concrete implementation of the EPR schemes can lead to a high collection rate cannot be assessed in this study. This would require a separate detailed evaluation of the individual collection systems. Generally, supportable features of an EPR are for example collection of waste oil free of charge, communication and information of waste oil generators or a comprehensive area-wide collection system with sufficient collection intervals, without knowing how these features actually translate into increased collection figures.

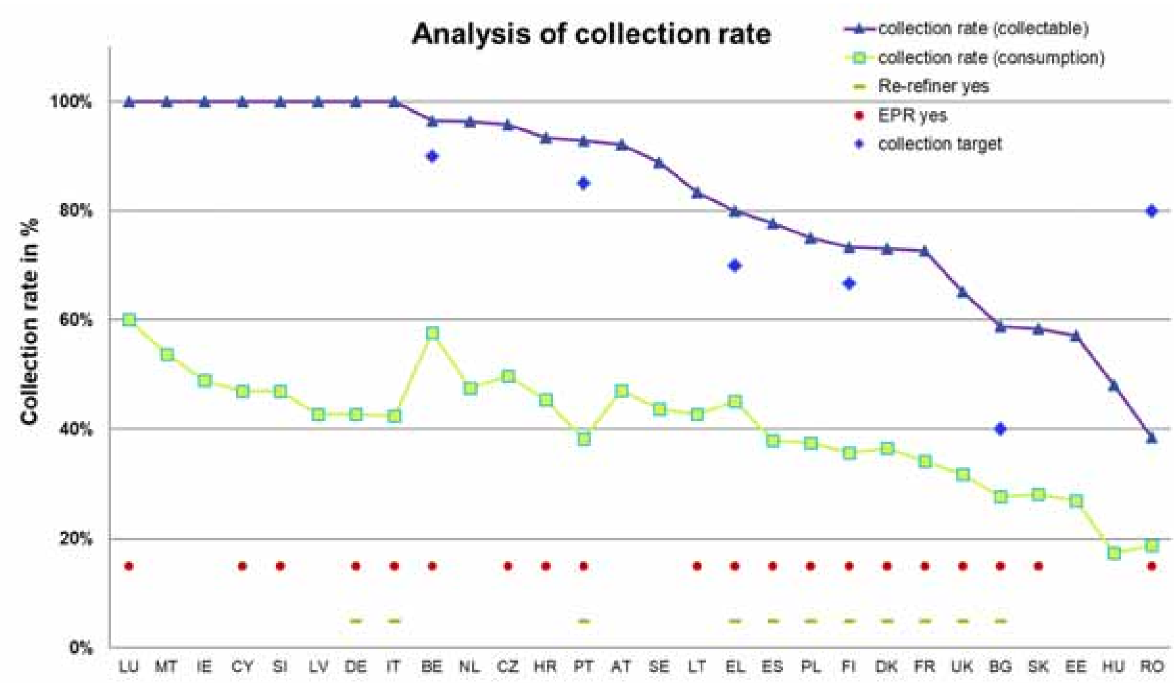
Quantitative collection targets for waste oil have been identified for 6 MS. The definition of the target, however, cannot always be clearly determined. In the case of Romania we assume that “used oil management” includes collection of waste oil[60]. Bulgaria’s target of “recovery of at least 40%” also remains rather unclear. Furthermore, we consider that all collection targets are based on the amount of collectable waste oil (apart from Romania’s and Bulgaria’s target: PoM).

The simple existence of a concrete quantitative collection target is, however, not sufficient to achieve a high collection rate. It can be concluded that targets need to be reasonably high and have to be accompanied by suitable measures to achieve the target. Considering a collection target on the basis of the collectable quantity, a target value of 100% should be aimed at. This means that all avoidable losses are actually avoided and no potentially illegal activities take place. Figure 17-1 would suggest a reasonable range for a collection target to be about 40% to 60% on the basis of the amount placed on the market. Even with a target value of 50% (the mean value between 40% and 60%), it must be assumed that individual MS would have to collect more waste oil than the theoretically collectable amount would correspond to.

The simple availability of a **re-refinery** in a country does not seem to influence the collection rate. Belgium for example has no re-refinery but nevertheless has a very high collection rate.

[60] No further details about the target could be found, however, only what is collected can subsequently be treated. A 60% or 80% target based on PoM remains unclear as only about half of the amount PoM is on average collectable.

Figure 17-1 Analysis of collection rates (2017) and its dependencies[61]



Source: Table 17-1, Table 27-4

Figure 17-2 shows the share of the collected waste oils being treated in re-refineries ('Regeneration'). The MS with the highest regeneration shares are listed on the left. Regeneration considers re-refining in the MS itself and export to re-refining in other MS. A large share of MS reaches 70% or 80% up to 100% of regeneration. A group of 11 MS regenerates 0%[62] or only up to 20% of its waste oil. The few remaining MS are between 30% and 70% regeneration.

In order to identify potential dependencies of the regeneration, the following additional parameters are included in the figure: regeneration targets in %, existence of re-refineries, missing restrictions regarding co/incineration of waste oil ('No restriction') and existence of end-of-waste (EoW) criteria.

Quantitative regeneration targets have been identified for 7 MS. All of these MS but Poland and Slovakia display high shares of regeneration between about 70% and 100%. MS that have set themselves a target are not necessarily identical to MS that have re-refineries themselves (Lithuania does not have its own re-refineries).

11 MS have **re-refineries** in their territories. As expected, most of these MS belong to the group of MS with the highest shares of regeneration. However, Poland for example and in particular the UK display comparatively low shares of regeneration. In the UK, no specific requirement prioritising re-refining of waste oils and no specific restriction hampering the use of waste oil as a fuel exist, see Table 16-1 and Chapter 14.

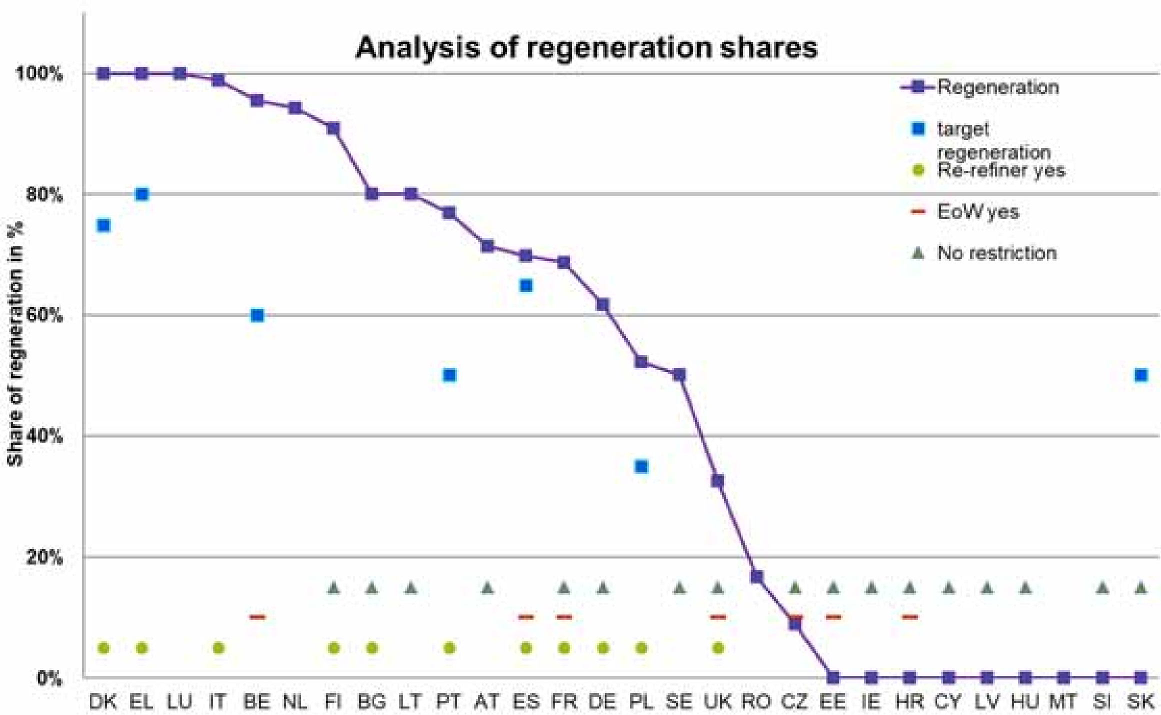
[61] The data is not suitable for the evaluation of the national targets, as the targets and their scope have been specifically adapted for this analysis.

[62] MT is unclear and might also regenerate 100%. According to GEIR 2019 waste oil is exported not for re-refining but 'other'; according to EC-WFD 2018 all waste oil is exported for regeneration.

Furthermore, at least 17 MS (12 of them without their own re-refineries) do not have any **specific restriction** regarding the export of waste oil for incineration or co-incineration (e.g. in cement plants) and/or a specific requirement favouring the regeneration of waste oil. Other MS, however, do have such specific restrictions. For example, in Luxembourg the authority can object to cross-border transfers of waste oil for incineration or co-incineration so that the regeneration of waste oil can be given priority (EC-WFD 2018). Figure 17-2 shows that most MS without specific restrictions and without re-refineries in their territories have a share of regeneration of 0% (apart from LT, AT, SE). The UK and also Germany (see Chapter 25 Subsection v), where no clear and unmistakable priority for recycling over energy recovery can be identified, display comparably low shares of regeneration.

End-of-waste criteria were already discussed in Section 16. For some MS EoW criteria correlate with high shares of energy recovery and low shares of regeneration, for others, Belgium, Spain and France, not.

Figure 17-2 Analysis of regeneration shares (2017) and its dependencies[63]



Source: Table 17-1, Table 27-4

It can be concluded that high shares of regeneration are found in MS that have implemented through measures a clear priority for regeneration. High shares of regeneration correlate with:

- Quantitative target setting for regeneration; and
- With some limitations, availability of re-refineries in the MS' own territories.

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[63] The data is not suitable for the evaluation of the national targets, as the targets and their scope have been specifically adapted for this analysis. Regeneration share = share of collected waste oil for re-refining.

Low shares of regeneration correlate with:

- Missing restrictions for the export of waste oil to incineration and co-incineration when there is no re-refinery in their own country.

The assessment of EoW criteria does not lead to a clear result. The analysis indicates that EoW criteria defining fuel products derived from waste oil might be a negative driver towards promoting regeneration to base oils.

18 Suggestions for follow-up work

The evaluation of the waste oil mass flows in the EU-28 showed that the main area for improvement is achieving higher collection rates of waste oil. For achieving this objective of higher collection rates two main aspects should be further explored. The Commission should investigate the possibility of mandatory collection targets for waste oil. And furthermore, the possible contribution of EPR systems to higher collection rates should be examined.

Target for a collection rate of waste oil

The study considered two different methodologies for measuring and monitoring the collection of waste oil on MS level (see Figure 17-1 and Chapter 8):

- A collection rate based on the consumption of lubricant oil: amount of collected waste oil divided by the amount of lubricant oil placed on the market;
- A collection rate based on collectable waste oil: amount of collected waste oil divided by the amount of collectable waste oil.

Concrete targets for both collection rates would have to be developed. It would be conceivable to develop targets that provide for a time-dependent increase in the collection rate. When evaluating the two different methodologies advantages and disadvantages of both options would have to be analysed and compared with each other. The Commission could either introduce one of the two methods as a basis for a collection target or offer Member States the freedom to choose between the two options. Both methods require a separate target.

The collection rate based on collectable waste oil requires, however, the development of an additional methodology for how to calculate the collectable waste oil. Therefore, a model for the calculation of the collectable waste oil would have to be developed.

Such a model could for engine oil make use of the approach described in Chapter 11. The remaining oils could be calculated in a simpler way by linking the individual oils and uses with their specific return rate. In a first step default values for return rates, e.g. by applying the figures in Table 6-1 could be used. However, it would be preferable for each MS to develop its own country-specific rates, which would require its own project work in each MS. The prerequisite for this approach, with specific return rates for individual oils and applications, would be that all MS have available the amount of different oils and applications. If this is not the case, the data would first have to be newly generated.

Following other aspects are also of interest:

- The model could be used to develop the basis for target setting of collection rates.
- The model could be applied for the calculation of MS specific "collectable waste oils".
- The development of a country-specific model would require specific data input from MS.
- Country-specific data on lubricants PoM and collectable waste oil are to a certain extent intransparent. A model could help to improve this situation.
- Such a model could be used to cross-check and validate data provided by MS.
- The model and general approach for collectable waste oil could make use of a similar approach as for the model which was developed for WEEE (e.g. MS-specific model) and is used for the collection targets of WEEE.

The main advantage of modelling collectable amounts of waste oil is that this approach would consider unavoidable losses and thus in theory provide a realistic picture of the true collectable amount of waste oil.

However, this method and the modelling of collectable waste oil also have a number of disadvantages:

- The collectable amount of waste oil and the actually collected waste oil (for the calculation of the collection rate) will be based on two different methodologies and data bases which will not necessarily match (e.g. due to different scopes). For example collection rates of higher than 100% might result, see example in Chapter 8, Figure 8-2.
- The accuracy of the modelling method is unclear. Whether, e.g. 10% deviations from the target value are due to inaccuracies or real unavoidable losses of waste oil may not be validated. It should be examined whether such a theoretical approach can reflect reality with sufficient reliability.
- Quality differences in modelling between MS cannot be ruled out.
- The modelling and calculation of the collectable amounts of waste oil would be a demanding, complex and labour-intensive task.

Whether the advantages of this approach justify the complexity and the high effort for the developing of such a modelling is an issue for analysis and assessment in the next steps.

The clear advantage of a collection target based on PoM would be its simplicity and transparency in the calculation. The general disadvantage is that unavoidable losses would not be addressed. Therefore, it becomes difficult when a MS misses the collection target. Then it is unclear whether too little waste oil has actually been collected or the country-specific unavoidable losses are already higher than the target value.

EPR schemes

Apart from collection targets, EPR schemes present another option to increase the collection of waste oil. Therefore, the Commission could examine the possibility of making EPR schemes mandatory. However, since EPR systems alone are not a guarantee for higher collection rates, concrete standards for the tasks, obligations and structure of the EPR systems have to be developed. Therefore, success criteria of EPR schemes for higher collection rates of waste oil need to be analysed and assessed. Aspects and measures that should be investigated regarding their feasibility and effectiveness are for example:

- Collection of waste oil directly from the generator; a comprehensive area-wide collection system with sufficient collection intervals;
- Network of collection points, density of the collection points, distance to the collection point;
- A measure specifying that only waste oils that are properly separated are collected free of charge;
- The need for financial support by the EPR scheme to ensure the re-refining of waste oil (see the example of CONOU in Chapter 14). Is there a risk that waste oil is used as fuel due to economic reasons? Is an EU-wide harmonised approach necessary for this or should this be decided at MS / EPR level?
- A minimum portion of the EPR budget should be used for information campaigns; Cost and benefits of such campaigns should be evaluated;

- A portion of the EPR budget could be used for cleaning up oil-contaminated soil and groundwater.

Avoidable losses of waste oil

With regard to avoidable losses of waste oils, the concrete background for such losses and potentially illegal activities at MS level is still unclear. For example, burning waste oil in small-scale heaters for heating purposes and engine oil change of passenger cars carried out by private car holders are regarded as possible causes of losses. To this end, the Commission could systematically evaluate the concrete legal basis in the individual MS and examine whether there is a need for action. In doing so, it is necessary to examine whether these are matters that could be addressed via introduction of legal requirements or whether these are implementation and enforcement issues. In general, the Commission could examine which of the potential measures could be imposed at EU level and which would need to be implemented at MS level.

Regeneration of waste oil

Apart from higher collection rates the other main objective should be achieving a higher share of re-refining of waste oil.

The waste management hierarchy prioritises the regeneration of waste oil above energy recovery (use as a fuel or co-incineration in, e.g. cement kilns). Member States must promote the waste hierarchy through legislation and political measures.

Therefore, first of all the development of a quantitative target for re-refining of waste oil on EU-level should be explored as there seems to be a clear correlation between MS that have established (significant) regeneration targets and the regeneration rates reported and analysed in this study.

A concrete target value for re-refining of waste oil but also how this target should be implemented in MS without own re-refineries (including reporting obligations and monitoring) are aspects that should be explored and assessed. Further aspects to be considered are the share of waste oil not suitable for re-refining and the re-refining capacities in comparison to a potential re-refining target including possibilities for adaption of capacities.

As a further policy measure, fiscal incentives supporting regeneration of waste oil or restricting energy recovery (e.g. a carbon dioxide tax) should be examined.

“Study to support the Commission in gathering structured information and defining of reporting obligations on waste oils and other hazardous waste”

Part 2 Spent solvents and other hazardous liquid chemical wastes

Final Report

19 Introduction

19.1 Objective and scope

Together with waste oils, spent solvents and other hazardous liquid chemical wastes constitute a relevant share of total European hazardous waste generation. While no specific targets have been set in the WFD with respect to the generation, collection or treatment of solvents and other hazardous liquid chemical wastes in the European Union, it is clear that these hazardous wastes need to be handled in an environmentally safe manner and in compliance with the waste hierarchy. In order to promote compliance with these two paramount requirements in a first step a quantitative analysis of the relevant flows is needed for spent solvents and other hazardous liquid chemical wastes. Moreover, a better understanding of the possibilities to recycle these streams is required.

In order to provide a structured overall picture of the situation in the EU Member States a material flow analysis for spent solvents was conducted. It included all stages along the lifecycle from primary production via the use phase to their end-of-life as well as a quantitative analysis of the treatment options currently applied to spent solvents. Solvents can be clearly identified via their uses and a common notion of relevant representative substances also exists (see Chapter 19.2). For other hazardous liquid organic chemicals, however, no practicable definition for a set of representative substances and corresponding applications could be elaborated. As a consequence the analysis of other hazardous liquid chemical wastes was only included in the waste stage based on a defined set of representative List of Waste (LoW) codes.

Concerning the waste stage only hazardous waste streams were considered. The Waste Framework Directive (WFD) gives a clear definition of "hazardous" as "any waste displaying one or more hazardous properties (HP) of the fifteen HP listed in Annex V WFD".

For solvents, when speaking of individual substances which upon use become waste, all relevant substances identified as solvents (see Chapter 19.2 and 20) generally are to be treated as hazardous waste.[64] The concrete classification of these substances as hazardous wastes according to Annex III WFD then depends on the composition of the specific waste stream. Several substances lead to hazardous properties when present in small concentrations (<< and < 5%)[65], while other substances require higher concentrations (between 10-25%)[66]. For some substances no general concentration limit is defined in Annex III WFD[67], and hazardous properties are assigned based on testing or on reasonable assumptions considering the composition of the waste. In general compositions which will be relevant for recycling will have elevated solvent contents and as a general rule solvent recyclers have confirmed that spent solvents are always hazardous waste (ESRG 2019).

Thus, the analysis of the waste stage was carried out for hazardous entries in the LoW for spent (organic) solvents as well as solvent-containing waste streams from relevant

[64] See e.g. GESTIS Substance Database; http://gestis.itrust.de/nxt/gateway.dll/gestis_en/000000.xml?f=templates&fn=default.htm&vid=gestiseng:sdbeng, last access: 19/12/16

[65] e.g. methanol, hexane, toluene, THF, chlorinated or nitrogen-containing solvents

[66] e.g. 1-propanol, butanol, cyclohexane, ethylene glycol, xylenes, MIBK, acetonitrile or acetic acid

[67] e.g. ethanol, IPA, acetone, butanone, ethyl or butyl acetate

applications[68] in line with the definition in (JRC 2018). In addition, based on the criteria of referring to hazardous, liquid and organic wastes several LoW codes were identified and considered as other hazardous liquid chemical wastes. Aqueous wastes were generally excluded because of their diluted nature and correspondingly different options for adequate treatment (cf. JRC 2018). The LoW entries included in the study are described in Chapter 22 and included in Annex V.

For liquid waste solvent the term "spent solvent" is used. For solvent material recovery the term "solvent recycling" is generally used. Synonymous terms may be solvent regeneration or solvent purification, always meaning that a solvent is returned to a state where it can be used for solvent purposes again (although not necessarily in the same application as for its first use).

The scope of the study is the EU 28 Member States (MS). Depending on data availability for the material flow analysis the major reference years are 2016 and 2017 including some outlooks to earlier years.

The major data sources include publicly available statistics[69] , data and information from industry representatives[70] and the answers to the survey conducted as part of this study among the Member States´authorities concerned with hazardous waste management (MS survey 2019).

19.2 Definition, types and applications of solvents

According to Ullmann´s (2012) solvents are compounds that are generally liquid at room temperature and atmospheric pressure; they are able to dissolve other substances without chemically changing them; a high chemical resistance is an important prerequisite for the use of a liquid as a solvent. While inorganic solvents also exist (the most prominent example being water) the term "solvent" often implies "organic solvent" a notion that is also used for the present study.

A clear definition of "organic solvent" is provided in Article (46) of the Industrial Emission Directive (IED):

(46) 'organic solvent' means any volatile organic compound (VOC) which is used for any of the following:

(a) alone or in combination with other agents, and without undergoing a chemical change, to dissolve raw materials, products or waste materials;

(b) as a cleaning agent to dissolve contaminants;

(c) as a dissolver;

(d) as a dispersion medium;

(e) as a viscosity adjuster;

(f) as a surface tension adjuster;

(g) as a plasticiser;

(h) as a preservative;

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[68] e.g. coating applications

[69] in particular Eurostat

[70] in particular the European Solvents Industry Group (ESIG, primary production of solvents) and the European Solvent Recyclers Group (ESRG)

Additionally, uses as an extraction medium, in extractive distillation and for chromatography can be considered solvent uses (Ullmann´s 2012).

While the IED particularly mentions and defines organic solvents as VOC, non-VOC solvents also exist. The criterion used for differentiation in the IED is the vapour pressure: any solvent with a vapour pressure of ≥ 0.01kPa (at 20°C) or having a corresponding volatility under the particular conditions of use is VOC. According to this definition most solvents included in the analysis of the present study are VOC. Solvents having lower volatility which do not qualify as VOCs include some representatives of glycol-ethers or longer chain hydrocarbons.[71]

For the solvent recyclers a solvent is in general any liquid chemical which can be recovered in a recycling process to give a reuseable[72] liquid product (ESRG 2019).

As there are various applications, which rely on solvents and which have different demands concerning their performance (e.g. with respect to solvency power, evaporation rate or influence on viscosity and surface tension), a great variety of potential solvent substances exists (Ullmann´s 2012, ESIG 2018a). These can be classified into the main subgroups oxygenated solvents, hydrocarbon solvents and halogenated solvents. Moreover, nitrogen- or sulphur-containing solvents exist.

Representatives of the **oxygenated solvents** come from the chemical classes of alcohols, esters, ethers and ketones (Ullmann´s 2012, ESIG 2018b, OSPA 2018). The main alcohols are methanol, ethanol, n- and iso-propanol and different butanols. Ethers include dialkylethers, tetrahydrofuran and glycol ethers. The latter are either termed "E-series" or "P-series" depending on whether they are derived from ethylene oxide or propylene oxide, respectively (GEO 2019). Glycol ether acetates are also used as solvents. Other esters mainly include alkyl acetates (mainly ethyl and butyl acetates). The major representatives for ketones are acetone, butanone (methylethylketone, MEK) and methyl isobutyl ketone (MIBK).

Hydrocarbon solvents can be classified into aromatic and aliphatic solvents and mixtures. Representatives of aromatic solvents are toluene and xylenes (m-, o-, p-isomers), whereas benzene is subject to strict restrictions under REACH (REACH RS 2019)[73] and is thus no longer directly used as a solvent (ESIG 2019). It remains, however, an important chemical intermediate. Moreover, specifically defined aromatic hydrocarbon mixtures are marketed (ESIG 2018b, HSPA 2018). Aliphatic solvents include shorter chain alkanes (e.g. pentane, hexane), longer chain alkanes (paraffins, de-aromatised solvents and mineral spirits) and cycloalkanes (Ullmann´s 2012, ESIG 2018b, HSPA 2018). White spirit and heavy mineral spirit in general have some aromatic content (Phenix 2007).

Halogenated solvents mainly refer to **chlorinated solvents**. According to ECSA (2019) the main chlorinated substances in use as solvents are methylene chloride (dichloromethane, DCM), trichloroethylene (TRI) and tetrachloroethylene (perchloroethylene, PER). TRI is listed in the REACH authorisation list (REACH Annex

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[71] Generally, the Hydrocarbon Solvents Producers Association (HSPA) states that carbon numbers > C_{15} do not contribute significantly to overall vapour exposure because of their very low vapour pressures (HSPA 2018).

[72] based on technical and legal requirements.

[73] REACH restriction benzene: https://echa.europa.eu/documents/10162/59f436ca-8afa-4adf-b108-27d7bc8a7751, last access: 19/11/04; incl. a special provision for "substances and mixtures for use in industrial processes not allowing for the emission of benzene in quantities in excess of those laid down in existing legislation". Also use

XIV)[74], meaning that since 2016 it can only be used with special authorization or when falling under an exemption.[75] Today the use of TRI as an industrial solvent is approx. 20 % of its total use (ECSA 2019). Also with PER its major use is as a feedstock for other chemicals and polymers followed by its use as a solvent and as a reactant for catalyst regeneration in the petrol industry (ECSA 2019). For methylene chloride ECSA (2019) only describes solvent uses.

Other chlorinated substances with very limited solvent use include carbon tetrachloride (CCl_4), chloroform and dichloroethane (ethylene dichloride, EDC). CCl_4 and chloroform are included in the REACH restricted substances list (Annex XVII), prohibiting their use in consumer applications (REACH RS 2019).[76] Dichloroethane (ethylene dichloride, EDC) is mainly an intermediate in PVC production. Its use as solvent is subject to authorisation under REACH and several authorisations exist.[77]

Nitrogen-containing solvents include amides (especially N,N-dimethylformamide, DMF and N,N-dimethylacetamide, DMAC), amines (e.g. triethylamine, aniline), 1-methyl-2-pyrrolidone (NMP) and acetonitrile. DMF, DMAC and NMP are Substance of Very High Concern (SVHC) under EU REACH regulation.[78] For NMP a restriction will be applicable as of 2020 (2024 for wire coating) (REACH RS 2019) and a restriction dossier for DMF was discussed in 2019 in view of a possible restriction. A typical **sulfur-containing solvent** is dimethyl-sulfoxide (Ullmann´s 2012, ESRG 2019).

Table 19-1 lists the different solvent subgroups and some main corresponding substances in an exemplary manner. More comprehensive overviews can be found in ESIG (2019b) and Ullmann´s (2012). The substances considered in the analysis are described in Chapter 20 and listed in Table 20-1 and Table 20-2.

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[74] https://www.chemsafetypro.com/Topics/EU/REACH_annex_xiv_REACH_authorization_list.html, last access: 19/11/04

[75] Authorisations for TRI: https://www.echa.europa.eu/applications-for-authorisation-previous-consultations, last access: 19/11/04

[76] The use of chloroform for diffusive applications such as in surface cleaning and cleaning of fabrics is also restricted.

[77] Authorisations for EDC: https://www.echa.europa.eu/applications-for-authorisation-previous-consultations?diss=true&search_criteria_ecnumber=203-458-1&search_criteria_casnumber=107-06-2&search_criteria_name=1%2C2-dichloroethane, last access: 19/11/04

[78] https://www.chemsafetypro.com/Topics/EU/REACH_SVHC_Finder.html, last access: 19/11/04, also includes information on whether a substance is subject to authorization under REACH.

Table 19-1 Organic solvents – subcategories and examples

Solvent category	Chemical classes	Example substances
Oxygenated solvents	Alcohols	Methanol, ethanol, n-propanol, isopropanol (IPA), butanols
	Ethers	Diethylether, tetrahydrofuran Glycolethers (E-series, P-series)
	Esters	Ethylacetate, butylacetate Glycolether acetates
	Ketones	acetone, butanone (MEK), methyl isobutyl ketone (MIBK)
Hydrocarbon solvents	Aromatics Alphatics	Toluene, xylenes, aromatic solvents Pentane, hexane, cyclohexane, heptane, paraffins, de-aromatised solvents White spirit, heavy mineral spirit (some aromatic content)
Halogenated solvents	Chlorinated solvents	methylene chloride (DMC), trichloroethylene (TRI), perchloroethylene (PER)
Nitrogen-containing solvents		N,N-dimethylformamide (DMF), DMAc, 1-methyl-2-pyrrolidone (NMP), acetonitrile, triethylamine, aniline
Sulphur-containing solvents		Dimethyl sulfoxide (DMSO)

Today, solvents are still in general fossil-based, i.e. derived from crude oil (mainly via naphtha) and natural gas. Oxygenated solvents are produced from olefins, while most of the hydrocarbon solvents are directly sourced from refineries (ESIG 2018a). An important exception is ethanol where the volumes seem to be largely bio-based (see Chapter 20.1). Representatives of bio-based solvents (drop-in and new compounds) are discussed e.g. in RTB (2019) and Sheldon (2019).

According to their purposes of dissolving, dispersing, or adjusting material properties as defined above solvents have a vast field of application. Various uses are described in e.g. Ullmann´s (2012), ESIG (2018c & 2018e), JRC (2018 & JRC 2019). Some important applications and examples for uses are summarized in Table 19-2.

Table 19-2 Examples for applications of organic solvents

Field of application	Examples
Coating applications	paints and varnishes (e.g. for vehicle coating), printing inks, adhesives, wire winding, coil coating
Cleaning	industrial cleaning (e.g. automotive metal degreasing, cleaning in the electronics industry), professional cleaning (e.g. dry-cleaning of textiles), household cleaning products
Organic synthesis	e.g. as reaction medium, for downstream processing in the (fine) chemical and pharmaceutical industries
Agrochemicals	e.g. carriers, emulsifiers in biocidal products
Cosmetics and disinfection	e.g. perfumes, nail polish, disinfectant rinses
Automotive applications	brake fluids, antifreeze agents, windscreen wash
Food sector	extractions, e.g. seed oil
Rubber manufacture	e.g. manufacture of tyres
Polymer manufacture	as process chemicals or blowing agents for polymer foams
Extraction of fossil resources	Oil drilling, oil field chemicals, metal mining and extraction

What is common to all uses is that the solvent itself is not chemically altered, the chemical stability being an important characteristic in the choice of the adequate solvent for an operation (Ullmann´s 2012).

This aspect has to be stressed in view of the material flow analysis: almost all substances which are relevant for solvent use also have uses as chemical intermediates. With respect to their end-of-life treatment only the fraction of the substances which remains chemically unchanged during use is considered. Thus, the solvent share (fraction of the chemical going to solvent use) is an important parameter needed to differentiate from its use as intermediate (or other uses, e.g. in fuels). The reported initial production volumes for the respective substances have to be adapted accordingly (see Chapter 20). Concerning a solvent´s fate, moreover, the degree of how dissipative uses are is important with respect to the possibility to collect it after use. For this the distinction between industrial, professional and consumer uses is helpful in some cases. As an example, in consumer uses there is no possibility to collect solvents which evaporate during application, while for industrial and some professional uses off-gas capture systems are operated (see also Chapter 21 and 24.2.2) and are a source of potentially recoverable solvent.

In general, many solvents can be used in one application and various applications can use the same solvent provided that it fulfils the technical requirements (determined by its physico-chemical properties).

An overview of different applications including the description of related example substances can be found in Ullmann´s (2012). ESIG (2018e) provides a list for various applications indicating the corresponding solvent types (by chemical class of solvents for hydrocarbon and oxygenated solvents).[79] A detailed description of the various coating applications including indications on the solvents used can be found in the draft BREF document on Surface Treatment using organic Solvents (JRC 2019). Solvents used in organic syntheses are reviewed by Sheldon (2019) including a discussion of the evolution in this field with respect to environmental and health concerns. Various uses of NMP, DMF and DMAC are described in the RMOA[80] on aprotic solvents (EC-ECHA 2018).

Tracing the solvents by substances through the various applications is hardly possible. A break in the material flow analysis hence originates from the fact that in the production phase (and also after being recovered as regenerated solvents with EoW status) the solvents are known as individual substances while in the use phase and the waste stage they are defined by their use/application of origin.

For illustrative purposes some solvent substances and their respective uses are presented in the following.

Solvents used in **organic syntheses**, e.g. in the pharmaceutical and (fine) chemical industry, are various and are mainly either used as a carrier/reaction medium in the synthesis itself or in downstream purification processes. Important solvents include for example alcohols (methanol, ethanol, propanol, butanol), ketones (acetone, MEK, MIBK), alkyl acetates and ethers, toluene, tetrahydrofuran, chlorinated solvents (dichloromethane, chloroform), nitrogen-containing solvents (DMF, DMAC, NMP, acetonitrile) and acetic acid (ESRG 2019, Sheldon 2019, Seyler et al. 2006).

For **metal degreasing** as well as **dry cleaning** perchloroethylene is an important solvent but also non-chlorinated solvents may be used. For dry-cleaning, paraffins (C9-C14 aliphatics) are applicable, and for degreasing formulations different hydrocarbon categories (hexane and longer-chain aliphatics) and oxygenated solvents (ketones, alcohols, and glycol ethers and esters) (ESIG 2018e). TRI is also used for industrial metal degreasing, e.g. the cleaning of storage tanks for liquid oxygen and hydrogen (ECSA 2019). An example solvent for home window cleaning is isopropyl alcohol (IPA) (ESIG 2018a).

Ethanol is used in **perfumes and cosmetics** (ESIG 2018a, RTB 2019). Other solvents used in cosmetics include ethyl acetate and acetone in nail polish (ESIG 2018a, RTB 2019). IPA and ethanol are also used for **disinfection** purposes in consumer and professional uses (ESIG 2018a, RTB 2019).

According to ESIG (2018e) solvents used in **agrochemicals** include aliphatics, ketones, alcohols and glycol ethers/esters.

Extraction agents used in the **food sector** (in production of, e.g. seed oil, fragrances, proteins, caffeine and others) include hexane, MEK, MIBK, Acetone, IPA (ESIG 2018e) and ethanol (RTB 2019).

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[79] https://www.esig.org/wp-content/uploads/2018/03/Managing-the-health-risks-of-solvent-exposure-simple.pdf, last access: 19/11/04. A table relating the numbers of the example hydrocarbon solvents categories to the respective substances can be found at: https://www.esig.org/wp-content/uploads/2018/08/HCS-key-data-2018_07_23-Final-1.pdf, last access: 19/11/04.

[80] Regulatory Management Option Analysis

Examples for the coatings sector include **paints and thinners** (solvent mixtures), where e.g. alcohols, acetates, glycol ethers and glycol ether acetates (Ullmann´s 2012) but also ketones and various aromatic and aliphatic hydrocarbons (ESIG 2018e) are used. An important application is vehicle coating. For wire coating (winding wires) JRC (2019) mentions n-methyl-pyrrolidone (NMP), naphtha and other aromatics as typical solvents for enamels (coatings).

In the **printing industry** ethanol and ethyl acetate are used in flexography and non-publication rotogravure printing, while publication rotogravure printing relies on one single solvent: toluene (JRC 2019, Tebert 2019). Low-boiling oils in the ink as well as in some cases IPA or ethanol in the dampening solution are used in heatset offset printing.[81] The cleaning agents in heatset printing are predominantly naphthenic and aliphatic hydrocarbons and increasingly high-boiling hydrocarbons with a flashpoint of > 100 °C and vegetable oil esters and/or mixtures of hydrocarbons and vegetable oil esters are used (JRC 2019).

Substances used in **adhesives** include different hydrocarbon categories as well as ketones and glycol ethers/esters (ESIG 2018e). Solvents used in the coil coating industry mainly include high-boiling aromatics; alcohols, esters and glycol ethers/esters as well as high-boiling ketones and aliphatics (JRC 2019).

For **automotive applications** solvents are used in antifreeze formulations (ethylene or propylene glycol), for brake fluids (glycol ethers, ESIG 2018e) or screen wash (alcohols, e.g. IPA for de-icing fluids, ESIG (2018a)). In general, de-icing solvents include alcohols and glycol ethers (e.g. for aviation, vehicles, conveyor belts, coal industry, ESIG 2018e).

Examples for solvents used in **polymerisation processes** are pentane, hexane and longer-chain aliphatics as well as alcohols, for rubber production processing aids of hydrocarbon-type solvents are employed (ESIG 2018e). As an example dearomatised aliphatic hydrocarbons with specific boiling point ranges are used in the production of tyres (ESIG 2018a). A prominent example for **blowing agents** for polymer foams is pentane. In the manufacture of carbon fibre composites ketones are used (ESIG 2018a).

Chemicals used in **metal mining** include aliphatic hydrocarbons which are used to extract metals such as copper, nickel, cobalt and zinc from ore (ESIG 2018a). As flotation frothers ketones and glycol ethers are employed (ESIG 2018e).

Solvents used in the **production of mineral oil and gas** include paraffins, ketones and glycol ethers for drilling and fracturing operations, as well as “oil field chemicals” (aromatics, paraffins, ketones; alcohols and glycol ethers) (ESIG 2018e). ESRG (2019) additionally mentions NMP for use in solvent extractions in the oil and gas industry.

Other uses of NMP as well as of DMF and DMAC include the manufacture of agrochemicals (fertilisers, pesticides, etc.), pharmaceuticals (e.g. antibiotics and novel contrast media), and fine chemicals, the manufacture of textiles/man-made fibres, wire and non-wire coating, as well as industrial cleaning, paint stripping formulations (EC-ECHA 2018).

[81] With respect to end-of-life treatment/recovery it has to be kept in mind that heatset inks are the only offset ink drying largely through evaporation whereas the other offset inks dry by oxidation or absorption in the paper (JRC 2019).

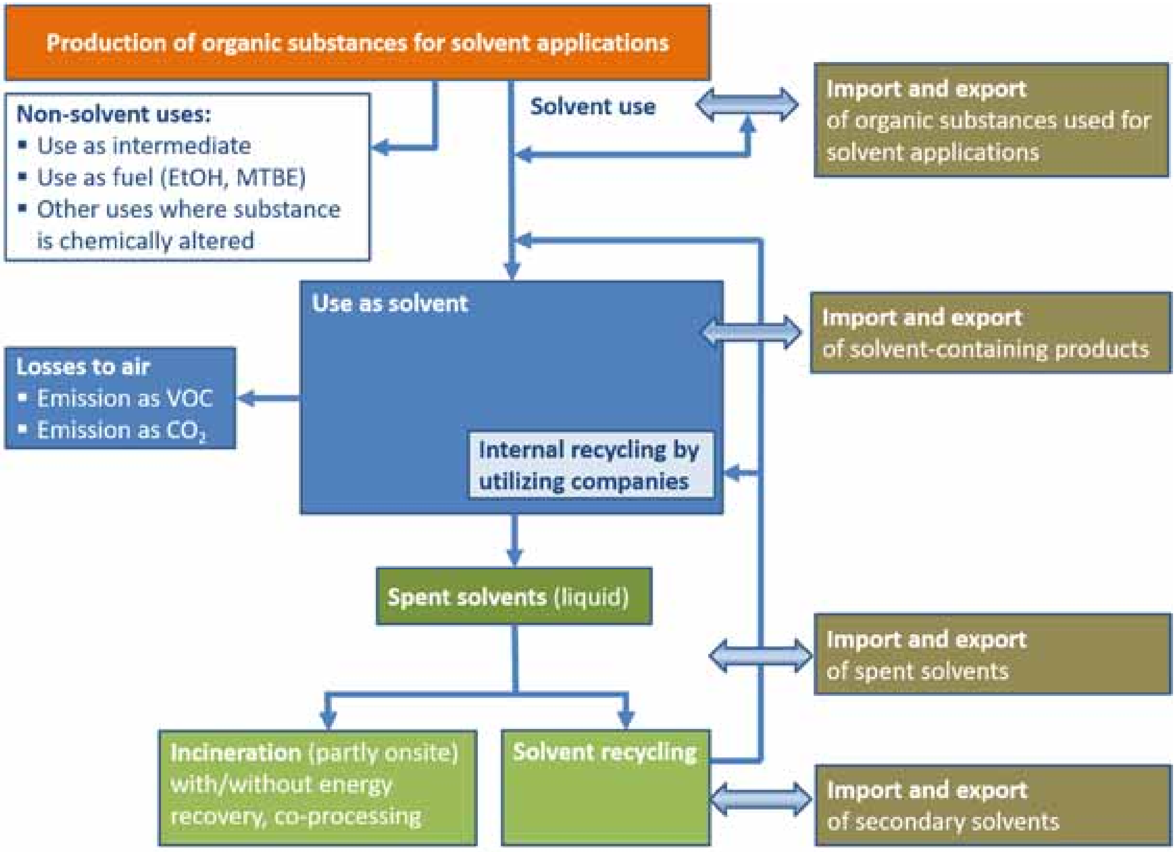
19.3 Approach: Material flow analysis and solvent recycling practices

The basic structure of the material flow analysis is illustrated in Figure 19-1. It includes the analysis of all lifecycle phases:

- Primary production
- Use phase
- Waste stage / End-of-life

For reasons of practicability the production phase focuses on substances used as solvents (other hazardous liquid organic chemicals are excluded, see also Chapter 19). Also for the use phase applications of solvents were analysed. In the analysis of the end-of-life phase in addition to spent solvents some considerations on selected other liquid organic waste streams are included.

Figure 19-1 Schematic of solvent flows through the lifecycle



With respect to primary production, a particular difficulty is related to the fact that most solvents are also used as chemical intermediates. This use often even dominates the production. Thus, in Chapter 20 in a first step the overall production is analysed and secondly those volumes going toward solvent use are identified to the extent possible (excluding the uses where the substances are chemically altered). Moreover, this chapter looks at the distribution of primary solvent sales within Europe and analyses the trade of substances used as solvents to/from the European Union.

Subsequently, Chapter 21 presents the analysis of the use phase of organic solvents with a focus on solvent losses due to evaporation. As solvents are in general emitted during their use (as emissions to air or liquid waste flows) no accumulation in the technosphere in the form of long-term stocks was considered. In principle, the material flow analysis of solvents also needs to take into account the trade in solvent-containing products. However, due to the variety of products and the fact that concrete information on their solvent content would have been required for each case this aspect could not be covered in the present study.

Those solvents which are not evaporated and released into air in the use phase result as liquid wastes. In Chapter 22, the generation and treatment of spent solvents in the European Union as well as the trade in spent solvents is analysed. Spent solvents are generally treated by incineration or recycled. The incineration of spent solvents can either be carried out with the pure objective of safe disposal or for energy recovery. For energy recovery the two options of recovery of useful heat and electricity and the use as an alternative fuel in production processes (co-processing) can be differentiated. The quantitative analysis of recycling considered treatment by an external solvent recycler.[82] An overview of the results of the material flow analysis is presented in Chapter 23.

Following the quantitative material flow analysis, Chapter 24 presents qualitative aspects with respect to the collection and recycling of spent solvents and the situation of the European recycling industry. Based on the results of the material flow analysis as well as on information obtained from representatives of the solvent recycling industry, the final two chapters discuss drivers for enhanced solvent recycling and give an outlook on further questions to be addressed (Chapters 25 and 26).

[82] The internal (within a plant / company) recycling practiced in several applications, particularly organic syntheses, was not part of the analysis but rather seen as integrated into the solvent use phase leading to reduced net consumption of solvents and correspondingly reduced waste output.

20 Primary production of solvents

20.1 Solvent production in the EU-28

For the analysis of the primary solvent production in the EU-28, a number of substances/categories currently most relevant in the context of solvents was first identified, based on information from stakeholders from the primary producers´ and recyclers´ side (ESIG 2019, ESIG 2018b, OSPA 2018, HSPA 2018, ECSA 2019, ESRG 2019). For these the related production quantities reported in the European Statistics for the production of manufactured goods (PRODCOM) were analysed. In a second step the flows of these substances going to solvent use were evaluated.

The substances and aggregates included in the analysis are shown in Table 20-1. The PRODCOM database reports data for the total and the sold production of organic substances under Codes 2014 xx xx corresponding to the NACE activity "C20.1.4 - Manufacture of other organic basic chemicals". The production volumes for the nitrogen-containing solvents could not be analysed via the PRODCOM database because the relevant substances are part of large aggregates (Table 20-2). In this case the only publicly available information on the EU-28 level are the tonnage bands for the volumes put on the market published by ECHA for each substance.[83] A dedicated PRODCOM entry exists only for aniline (and its salts).

Table 20-1 PRODCOM entries with link to solvents

Code	Label	Abbreviation
Oxygenated compounds		
20142210	Methanol (methyl alcohol)	MeOH
20142220	Propan-1-ol (propyl alcohol), propan-2-ol (isopropyl alcohol)	PrOH
20142230	Butan-1-ol (n-butyl alcohol)	n-BuOH
20142240	Butanols (excluding butan-1-ol (n-butyl alcohol))	BuOHs, other
20142310	Ethylene glycol (ethanediol)	Ethylene glycol
20142320	Propylene glycol (propane-1,2-diol)	Propylene glycol
20143215	Ethyl acetate	Ethyl acetate
20143219	Esters of acetic acid (excluding ethyl acetate)	Other acetates
20143271	Acetic acid	Acetic acid
20145215	Tetrahydrofuran, 2-Furaldehyde, Furfuryl alcohol, Tetrahydrofurfuryl alcohol and Piperonal	THF +
20146211	Acetone	Acetone

[83] EU-28 production plus net import, accessible via the ECHA search for chemicals: https://www.echa.europa.eu/web/guest/search-for-chemicals?p_p_id=disssimplesearch_WAR_disssearchportlet&p_p_lifecycle=0&_disssimplesearch_WAR_disssearchportlet_searchOccurred=true&_disssimplesearch_WAR_disssearchportlet_sessionCriteriaId=dissSimpleSearchSessionParam101401563361981587; last access: 29/09/2019

Code	Label	Abbreviation
20146213	Butanone (methyl ethyl ketone)	MEK
20146215	4-Methylpentan-2-one (methyl isobutyl ketone, MIBK)	MIBK
20146219	Acyclic ketones; without other oxygen function (excluding acetone, butanone, MIBK)	Acycl. ketones, other
20146310	Acyclic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives	Acyclic ethers
20146333	2,2-Oxydiethanol (diethylene glycol; digol)	Digol
20146339	Ether-alcohols and their halogenated, sulphonated, nitrated or nitrosated derivatives (excl. 2,2-oxydiethanol)	Ether-alcohols
only in DS-066341 on sold production:[84]		
20147400	Undenatured ethyl alcohol of an alcoholic strength by volume >=80% (important: excluding alcohol duty)	EtOH
20147500	Denatured ethyl alcohol and other denatured spirits; of any strength	EtOH, denat
Hydrocarbon compounds		
20141120	Saturated acyclic hydrocarbons	Acyclic HC, saturated
20141213	Cyclohexane	Cyclohexane
20141215	Cyclanes; cyclenes, cycloterpenes (excl. cyclohexane)	Cyclanes, other +
20141223	Benzene	Benzene
20141225	Toluene	Toluene
20141243	o-Xylene	o-Xylene
20141245	p-Xylene	p-Xylene
20141247	m-Xylene and mixed xylene isomers	m-Xylene + mixed
20141290	Other cyclic hydrocarbons	Other cyclic HC
20147320	Benzol (benzene), toluol (toluene), xylol (xylenes)	BTX
20147340	Naphthalene and other aromatic hydrocarbon mixtures (excluding benzene, toluene, xylene)	Naphthalene/ aromatics
Chlorinated compounds		
20141315	Dichloromethane (methylene chloride)	DCM
20141323	Chloroform (trichloromethane)	Chloroform
20141325	Carbon tetrachloride	CCl_4

[84] The codes referring to ethanol are given only in the Eurostat Prodcom database for sold production (DS-066341) not in that for total production (DS-066342); cf. https://ec.europa.eu/eurostat/data/database

Code	Label	Abbreviation
20141353	1,2-Dichloroethane (ethylene dichloride)	EDC
20141374	Trichloroethylene; tetrachloroethylene (per-)	TRI, PER

Table 20-2 PRODCOM entries relevant for nitrogen-containing solvents

Code	Label	Example substance
20145280	Compounds containing in the structure an unfused pyridine ring or a quinoline or isoquinoline ring-system, not further fused; lactames; other heterocyclic compounds with nitrogen hetero-atom(s) only (excluding compounds containing in the structure an unfused pyrazole ring, an unfused imidazole ring, a pyrimidine ring, a piperazine ring or an unfused triazine ring)	NMP
20144119	Other acylic monoamines and their derivatives; salts thereof	TEA
20144151	Aniline and its salts (excluding derivatives)	Aniline
20144370	Nitrile-function compounds (excluding acrylonitrile, 1-cyanoguanidine (dicyandiamide))	Acetonitrile
21102060	Acyclic amides and their derivatives, and salts thereof (including acyclic carbamates)	DMF, DMAC

While the database on sold production (DS-066341) provides information on the volumes actually sold by the producing companies, the total production (DS-066342) includes any production retained by the producing enterprise for further processing.[85] A comparison of the two databases showed that for many substances the reported quantities are roughly equal (assuming an error margin of +/-10 %, see Annex III). Information on ethanol is, however, only provided as sold production.

To give an idea of the volumes involved, Figure 20-1 to Figure 20-3 show the sold production for the selected substances for the reference years 2013-2017. These quantities still contain a more or less relevant use of the substances for other purposes, particularly as intermediates in further processing. The actual estimate of the volumes going to solvent use for each substance is discussed below (see Chapters 20.1.1 to 20.1.3).

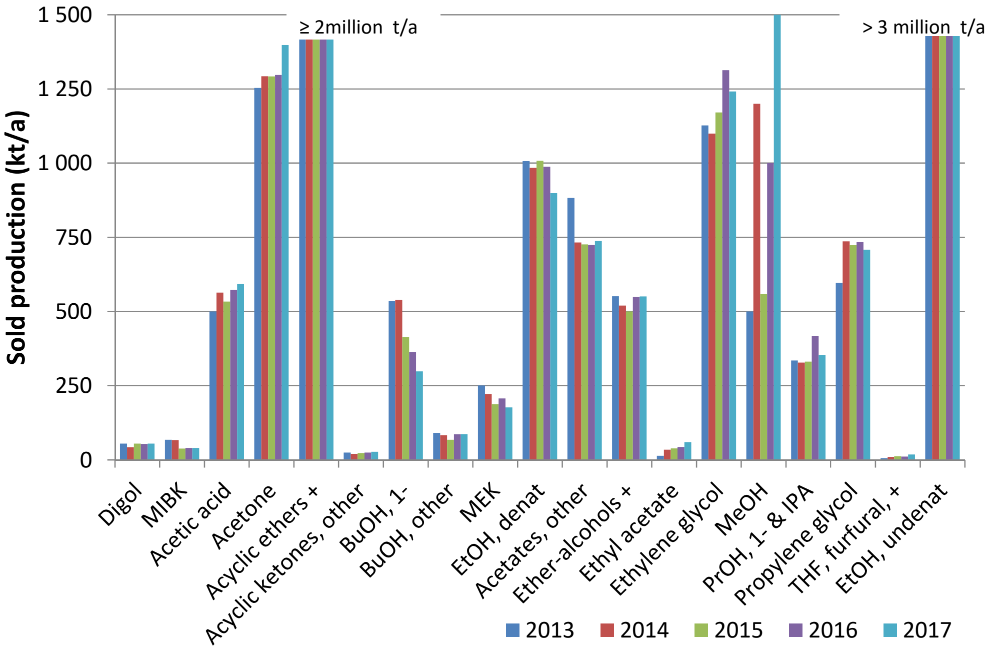
In general, the volumes are rather stable over the five years. An exception is methanol for which fluctuating quantities are reported. Overall, approx. 30 million tonnes per year are reported by PRODCOM as sold production for the categories

[85] See PRODCOM "Help for indicators"

analysed (out of approx. 100 million tonnes[86] per year reported for all organic compounds of NACE activity C20.14).

For the **oxygenated substances**, the volumes are dominated by ethanol and acyclic ethers which can be explained by the use as fuel or fuel additive (MTBE, ETBE, TAME and TAEE)[87]. For undenatured ethanol consumption as beverage/food also plays a role.

Figure 20-1 Sold production of selected oxygenated substances - all uses (PRODCOM DS-066341)



The total volume of sold ethanol (denatured and undenatured) reported by PRODCOM amounts to 5.6 billion L/a (not necessarily 100% pure). Comparing this volume to other sources shows that ethanol production is largely bio-based and higher volumes are indicated. According to EC (2019), approx. 6.4 billion L/a are produced, with ePURE[88] (2018) reporting 5.8 billion L/a for its members (each 100% pure). Overall, approx. 5 million tonnes[89] of pure ethanol are produced largely from biological origin.[90]

The other alcohols considered are produced in volumes of several hundred kt/a. From the ketone subgroup acetone is produced in very high quantities. Ethylene and propylene glycol, also substances with important intermediate uses, also show high volumes. They are followed by "other acetates" which beside alkyl acetates (other

[86] The three compounds with highest volume include the important intermediates ethylene, propylene and benzene (together nearly 30 million tonnes sold production reported for 2017).

[87] See, e.g. https://globalfuelethers.com/what-are-fuel-ethers/, last access: 19/10/25

[88] ePURE 'European renewable ethanol' is the industry association of European renewable ethanol producers.

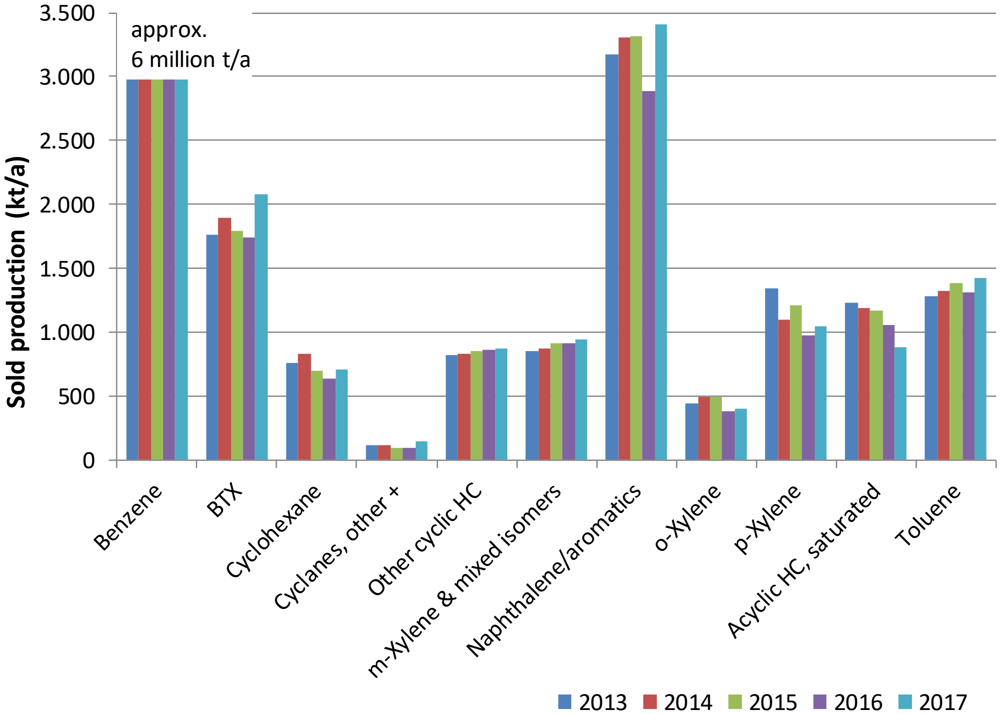
[89] The density of ethanol (0.79 kg/L) was used to convert the litres given into tonnes.

[90] See also https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/plants_and_plant_products/documents/ethyl-alcohol-from-agriculture-origin_en_0.pdf, last access: 19/11/05

than ethyl acetate) likely include the glycol ether acetates. In total, around 14 million t/a of these oxygenated substances are produced.

Among the **hydrocarbon substances** the highest volume is reported for benzene showing that although it is subject to REACH restriction it is still extensively used, mainly as intermediate, based on special provisions (REACH RS 2019).[91]

Figure 20-2 Sold production of selected hydrocarbon substances - all uses (PRODCOM DS-066341)[92]



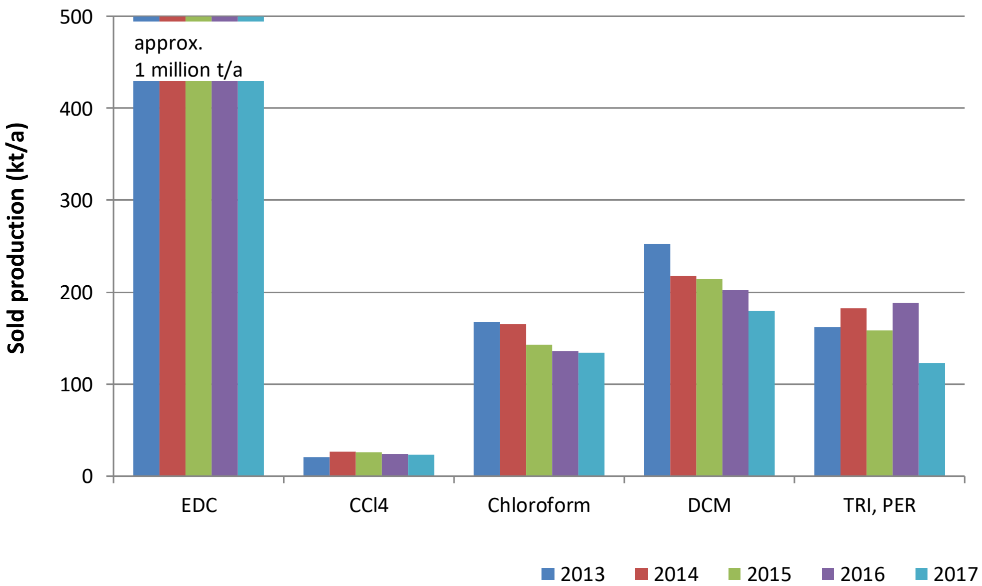
Next, the aggregate for naphthalene and other aromatic hydrocarbon mixtures shows a very high volume. P-xylene has high volumes due to its use as an intermediate in the production of PET while the other isomers are produced in lower quantities. For the aliphatic hydrocarbons only cyclohexane has a dedicated entry showing that it is the dominant cyclane. Saturated acyclic hydrocarbons (e.g. pentane, hexane, heptane) are all grouped in one category. The total volume of these hydrocarbon substances is around 18 million t/a.

[91] REACH restriction benzene: https://echa.europa.eu/documents/10162/59f436ca-8afa-4adf-b108-27d7bc8a7751, last access: 19/11/04; incl. a special provision for industrial uses and motor fuels.

[92] Prodcom statistics offer separate entries for benzene (20.14.12.23), toluene (20.14.12.25) and each xylene isomer (20.14.12.43, 20.14.12.45, 20.14.12.47) under the European CPA code 20.14.12 "Cyclic hydrocarbons". Moreover, a combined entry "Benzol (benzene), toluol (toluene) and xylol (xylenes)" (20.14.73.20, BTX) exists under CPA code 20.14.73 "Oils and other products of the distillation of high temperature coal tar, and similar products". This entry specifies one feedstock of origin but given the volumes reported under this entry it is suggested that also other feedstocks are included. Moreover, this entry does not explicitly indicate whether the substances are pure or in mixture.

For **chlorinated substances** a declining tendency can be observed. The very high volume for EDC is reportedly vastly due to its use as an intermediate in PVC production (ECSA 2019b).

Figure 20-3 Sold production of selected chlorinated substances - all uses (PRODCOM DS-066341)



In a second step, the volumes going toward solvent use were derived from the production quantities obtained from PRODCOM and based on industry estimates.

20.1.1 Oxygenated and hydrocarbon solvents

For oxygenated and hydrocarbon substances the production volumes as well as the fractions of the substances going to solvent use (solvent shares) have in general been rather constant over recent years (ESIG 2019). Expert judgment from industry suggests that high solvent shares exist for MEK, propanols and ethyl and butyl acetates. Except for ethyl acetate in official production statistics all other acetates are grouped in one large aggregate. According to ESIG (2019) solvent volumes for ethyl acetate and butyl acetate lie around 200kt/a each. For ethyl acetate this value is considerably above the officially reported sold production; a reason may be that some ethyl acetate is classified with the "other acetates" aggregate.

Approx. half of the production of MIBK and glycol ethers (with roughly equal shares of E- and P-series glycols) go toward solvent use while for butanols and acetone this value lies around one third; solvent use of cyclohexane and methanol is very low (ESIG 2019).

For this study a high solvent share was approximated with 90% of the PRODCOM values, whereas for very low solvent shares 5% were assumed.

The production of ethanol is mainly bio-based. From fossil-based ethanol less than 100kt/a go toward solvent use (ESIG 2019). The volume of bio-ethanol going toward industrial uses is approx. 600-800kt/a (RTB 2019 based on CEFIC data, EC 2019)[93].

[93] The volume reported by RTB (2019) is purely bio-based; the EC (2019) value may include (small) quantities of fossil ethanol as well as comparably small net imports (<5%).

However, no solvent share was available. Also ePURE (2019) reportedly has no information concerning the different uses within the industrial applications. Intermediate uses of bio-ethanol may include its use into ethyl acetate (and other ethyl esters), ethylene and fuel ethers (ETBE, TAEE). For overall bio-based solvent use, RTB (2019) reports a very low value of less than 0.5kt/a (mainly ethanol and 1,4-butanediol). For the present study the upper limit for fossil-based ethanol indicated by ESIG (2019) was assumed as approximation.

For acyclic saturated hydrocarbon solvents, information from ESIG suggests that approx. 100% of the sold production reported by PRODCOM for this aggregate goes toward solvent use. The major representatives are paraffins and white spirit with 250kt each as well as pentane and hexane with 200kt each (ESIG 2019).

Among the aromatic solvents benzene is generally no longer used as a solvent. Its use as a solvent in consumer and professional applications is banned under REACH and it is reportedly also no longer used as an industrial solvent (ESIG 2019). Smallwood (2002) already stated that benzene is among the solvents which have become almost completely obsolete. It is, however, still included in the list of substances regenerated by recyclers (JRC 2018, ESRG 2019) although it is no longer a regular task (ESRG 2019). Toluene, xylene isomers and other aromatic mixtures[94] according to ESIG are produced for use as solvents in volumes of approx. 1-1.5 million tonnes per year in Europe with roughly equal shares. From this a volume of approx. 400kt was approximated for toluene, xylene isomers and other aromatic mixtures, respectively.

Based on the above, the volumes shown in Table 20-3 were approximated for oxygenated and hydrocarbon solvents. Substances for which no solvent shares were identified, especially ethylene and propylene glycol and acetic acid, are not included. The **total sums to 4.3 million tonnes per year.** This value is below the 5 million tonnes per year reported for oxygenated and hydrocarbon solvents (JRC 2019, ESIG 2019). The difference can be explained by the overall data uncertainties and the fact that some solvents were neglected.

[94] e.g. A100, A150, see https://www.shell.com/business-customers/chemicals/our-products/solvents-hydrocarbon/aromatic-solvents.html, last access: 19/11/01

Table 20-3 Estimate for oxygenated and hydrocarbon solvents

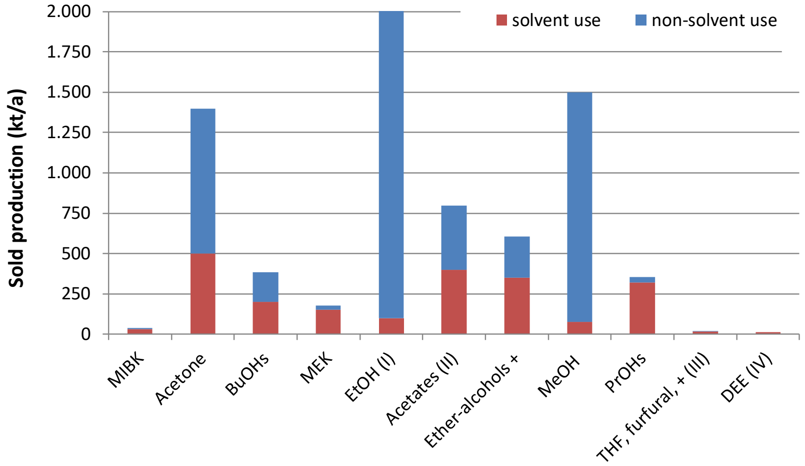
Substance / aggregate	Solvent use (kt in 2017)	Comment
Acetone	500	
MEK	150	
MIBK	20	
Methanol	75	
Ethanol	100	pure ethanol, upper limit of ESIG value as tentative estimate for fossil & bio
Propanols	320	
Butanols	200	
Glycol ethers (E+P)	350	approx. 50% E-series, 50% P-series
THF +	18	PRODCOM production, assuming 100% solvent use
Diethyl ether	12	PRODCOM value from 2007; assuming 100% solvent use, no information on solvent use of other acyclic ethers available
Ethyl acetate	200	
Butyl acetate	200	
Saturated acyclic HC	900	sum of acyclic HC solvent uses according to ESIG (2019) approx. equal to total sold value reported by PRODCOM
Cyclohexane	40	
Benzene	0	no solvent use assumed
Toluene	400	
Xylenes	400	
Aromatic mixtures	400	
Total estimated	**4300**	sum of above solvent substances
Total reported	**5000**	JRC (2019), ESIG (2019); difference explicable by data uncertainties and missing substances

Source: Own compilation based on PRODCOM, ESIG (2019), RTB (2019)

The solvent volumes compared to the overall sold production are shown in Figure 20-4 and Figure 20-5.

For the "THF, furfural+"- aggregate the whole sold production is indicated as an orientation. For acyclic ethers no information on solvent shares was identified either. The value for diethyl ether from 2007 as reported in PRODCOM is given assuming a 100% solvent share. Other acyclic ethers used as solvents are, e.g. di-isopropyl ether and MTBE (ESRG 2019, Sheldon 2019). However, no information on their volumes going toward solvent use could be identified.

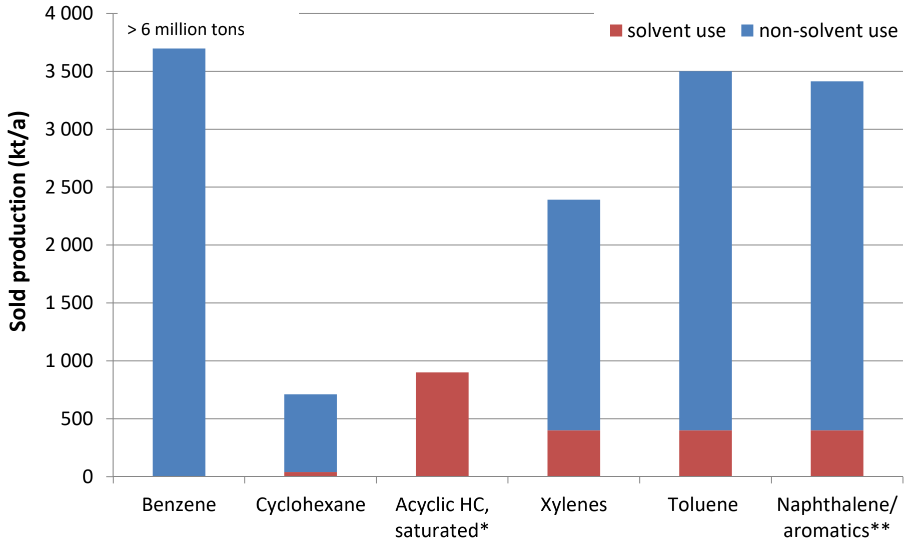
Figure 20-4 Oxygenated substances used as solvents and solvent shares



(I) total volume according to PRODCOM (undenatured plus denatured), solvent share pure ethanol (rough estimate)
(II) solvent use only ethyl and butyl acetate
(III) assuming 100% solvent use of this aggregate
(IV) solvent use: DEE for reference year 2007, assuming 100% solvent use; for other acyclic ethers no information on solvent use identified

Source: Own compilation based on PRODCOM, ESIG (2019), RTB (2019)

Figure 20-5 Hydrocarbon substances used as solvents and solvent shares[95]



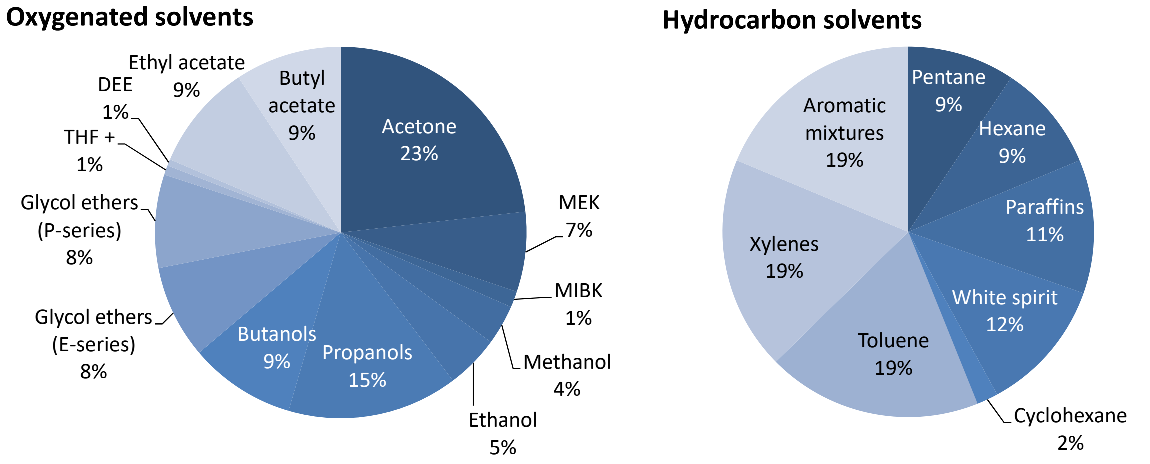
* solvent use mainly pentane, hexane, white spirit, paraffinics
** solvents "aromatic mixtures" (e.g. A100, A150)

Source: Own compilation based on PRODCOM, ESIG (2019), RTB (2019)

[95] In Figure 20-5 the other aromatic solvents are shown with the "Naphthalene/aromatics" aggregate (code 20.14.73.40). Another Prodcom entry where reporting might take place is code 20.14.12.90 "other cyclic hydrocarbons". For benzene,toluene and xylenes also a combined Prodcom entry (code 20.14.73.20) exists.

Figure 20-6 illustrates the estimated breakdown of oxygenated and hydrocarbon solvents by substance.

Figure 20-6 Breakdown of oxygenated and hydrocarbon solvents by substance (estimate)



Total: 2.1 million tonnes in 2017 **Total: 2.2 million tonnes in 2017**

Source: Own compilation based on PRODCOM, ESIG (2019), RTB (2019)

Summarising, a total of 5 million tonnes per year of oxygenated and hydrocarbon substances is reportedly produced in the European Union (JRC 2019, ESIG 2019). With the present analysis approx. 4.3 million tonnes were identified of which oxygenated and hydrocarbon solvents are produced in roughly equal quantities (see Table 20-3 and Figure 20-6). For the oxygenated solvents acetone, glycol ethers and propanols represent the majority. Butanols, MEK, ethyl and butyl acetate and to a smaller extent ethanol and methanol also contribute. Aromatic compounds account for more than half of the hydrocarbon solvent production. Approx. 20% each are shorter- and longer-chain alkanes, respectively.

20.1.2 Chlorinated solvents

According to ECSA (2019b) DCM and PER are the two most relevant chlorinated substances for solvent use. TRI is used in smaller volumes and subject to authorization under REACH.[96]

In PRODCOM TRI and PER are grouped into one aggregate. However, according to ECSA (2019b) TRI is rarely produced anymore in Europe and mostly imported when used. This implies that on average approx. 160kt/a of PER are produced according to PROCOM (SOLD production)[97]. The analysis of Comext-based PRODCOM data for the TRI/PER aggregate showed an import of up to 20kt (see Chapter 20.3). If all this is TRI and given a solvent share of 20% (ECSA 2019a), then it may be estimated that

[96] See ECHA list of authorized uses: https://www.echa.europa.eu/applications-for-authorisation-previous-consultations, last access: 19/11/04

[97] Total production average approx. 170kt/a (PRODCOM).

4kt of TRI are used as solvents in the EU-28. ECHA indicates a tonnage band of 10-100kt/a for all uses of TRI.[98] An export for the TRI/PER aggregate of approx. 100kt/a is reported, which would then be attributable to PER (see Chapter 20.3). This in turn would imply that the major share of PER produced in the EU is exported. Underlying the average production and trade over the last years reported for the TRI/PER aggregate roughly 50kt/a-100kt/a of PER are estimated to stay for use in the EU. This is, however, lower than the lower limit of the tonnage band indicated by ECHA (100-1000 kt/a)[99]. ECSA (2019) notes that there are no recent production volume figures available, as the number of manufactures is very small and hence figures cannot be published without affecting competition law. As with TRI the majority of PER uses today are intermediate uses (ECSA 2019b). However, no concrete value for the solvent share was available.

DCM is produced with a declining tendency in volumes around 200kt/a (180kt/a in 2017). ECSA (2019a) only describes solvent uses so that it is estimated that its solvent share is high.

The high sold production reported for ethylene dichloride (EDC) is vastly due to its use as an intermediate in PVC production (ECSA 2019b). ECSA (2019b) even estimates that its total tonnage on the European market is close to the upper limit of the tonnage band indicated by ECHA (1-10 million tonnes)[100] given its requirements for PVC production.[101] The total European production of EDC according to PRODCOM is approx. 3 million tonnes/a. Overall, the vast majority of EDC is used as an intermediate. Solvent uses authorized under REACH are known[102] but no aggregate data concerning the total volume was available.

According to ECSA (2019a) carbon tetrachloride is almost exclusively used as a chemical intermediate in closed systems in industry and for a few specifically permitted industrial solvent uses. Chloroform (trichloromethane) is mainly used as an intermediate for fluoropolymers, but also as an industrial extraction solvent or laboratory agent (ECSA 2019a). Already Smallwood (2002) states that carbon tetrachloride and chloroform have become almost completely obsolete as solvents. While the volumes for carbon tetrachloride are small the production of chloroform is in the same range as that PER. According to JRC (2018) and ESRG (2019), chloroform is among the substances regenerated by recyclers, as is chlorobenzene for which no dedicated PRODCOM entry was identified. The ECHA tonnage band for chlorobenzene is 10kt+.[103]

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[98] See https://www.echa.europa.eu/web/guest/information-on-chemicals/registered-substances/-/disreg/substance/100.001.062, last access: 19/11/05

[99] See https://www.echa.europa.eu/web/guest/registration-dossier/-/registered-dossier/14303, last access: 19/11/05

[100] See https://www.echa.europa.eu/web/guest/registration-dossier/-/registered-dossier/15430, last access: 19/11/05

[101] Plastics Europe indicates approx. 5 million tonnes (PlasticsEurope 2018) and based on the stoichiometry of the conversion the volume of EDC is higher than that of the vinyl chloride monomer making PVC (ECSA 2019b).

[102] See https://www.echa.europa.eu/applications-for-authorisation-previous-consultations?diss=true&search_criteria_ecnumber=203-458-1&search_criteria_casnumber=107-06-2&search_criteria_name=1%2C2-dichloroethane, last access: 19/11/05

[103] Full registration, in addition intermediate use is reported; see https://www.echa.europa.eu/web/guest/information-on-chemicals/registered-substances/-/disreg/substance/100.003.299, last access: 19/11/05

From the above, it is tentatively estimated that the production of chlorinated solvents is approx. 200kt/a (dominated by DCM, followed by PER). According to ESIG (2018d) chlorinated solvent use in the EU was approx. 140kt/a in 2013 and a generally declining tendency can be observed (PRODCOM, ECSA 2019b).

20.1.3 Nitrogen-containing solvents

Nitrogen- and sulfur-containing substances are all grouped into large aggregates so that no information on the volumes of relevant solvents can be obtained from PRODCOM. Table 20-4 gives the tonnage bands reported by ECHA. The tonnage bands include the European production as well as net imported quantities. According to ESIG (2019) at least NMP, DMF, DMAC and acetonitrile are produced in the European Union.

Table 20-4 Tonnage bands for nitrogen-containing solvents and DMSO –current values[104]

Substance	Tonnage band (kt/a)	Comment
NMP	10-100	only full registration, solvent share approx. 100%
DMF	10-100	in addition registration for "intermediate use only", solvent share approx. 100%
DMAc	1+	only full registration, solvent share approx. 100%
Acetonitrile	10-100	in addition registration for "intermediate use only", solvent share approx. 70%
TEA	10-100	in addition registration for "intermediate use only"
Aniline	1 000-10 000	in addition registration for "intermediate use only"; PRODCOM entry "aniline and its salts": 1 200 kt
DMSO	10-100	only full registration
Source: Tonnage bands (ECHA), solvent share (ESIG 2019)		

The tonnage bands are generally significantly lower than the total production reported for the corresponding PRODCOM aggregates (see Table 20-2).

According to PRODCOM the total production of aniline[105] lies at the lower range of the tonnage band but net imports may come in addition. Compared to the values of other

[104] Values currently indicated by ECHA as of October 2019; see https://www.echa.europa.eu/web/guest/search-for-chemicals?p_p_id=disssimplesearch_WAR_disssearchportlet&p_p_lifecycle=0&_disssimplesearch_WAR_disssearchportlet_searchOccurred=true&_disssimplesearch_WAR_disssearchportlet_sessionCriteriaId=dissSimpleSearchSessionParam101401563361981587; last access: 29/09/2019

[105] Aniline and its salts: 1170kt in 2017 (PRODCOM DS-066342, total production).

nitrogen-containing solvents aniline is produced in high quantities due to its use as intermediate.[106]

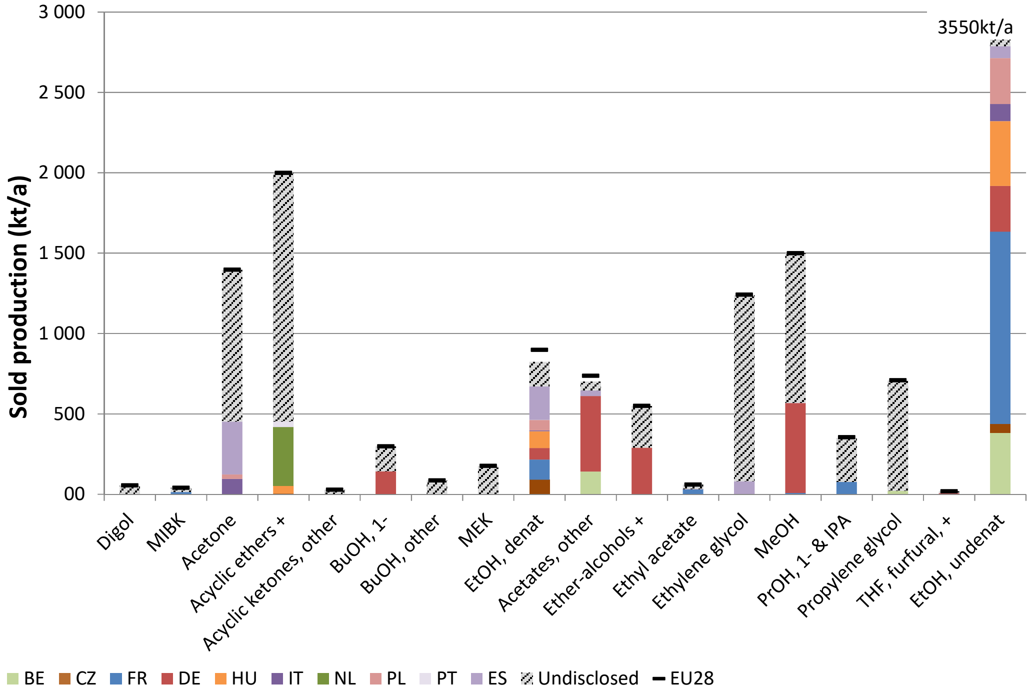
Data for DMAC indicate that its use has recently declined considerably: According to (ECHA 2012), the total consumption of DMAC in the EU was estimated at 11-19kt/a, with a European production of approx. 15-20kt/a (reference years 2011 and 2010, respectively). Compared to this the current tonnage band of 1+ kt is very low.

Based on the ECHA tonnage bands and the solvent shares indicated by ESIG (2019) for some representatives a solvent use of nitrogen-containing solvents at least in the range of several tens of thousand tonnes per year is to be expected in the European Union.

20.2 Solvent production in individual Member States

PRODCOM also provides information on the production of goods in each Member State (MS). However, due to confidentiality reasons in many cases the produced volumes cannot be disclosed. An analysis of the PRODCOM data by MS showed that on average the origin of 2/3 of the sold production reported for EU-28 remains undisclosed. This is exemplarily illustrated for the entries referring to oxygenated solvents in Figure 20-7.

Figure 20-7 Production of oxygenated solvents by Member State (PRODCOM, reference year 2017)



As a general observation ESIG (2019) indicates that the major producers of solvents are located in Belgium, Germany, France, the UK, the Netherlands, Spain and Italy. Except for the UK oxygenated and hydrocarbon solvents are produced in all of these MS (UK hydrocarbon solvents only). Smaller units are located in Greece and Finland, for hydrocarbon solvents only.

[106] See https://echa.europa.eu/brief-profile/-/briefprofile/100.000.491, last access: 19/11/12.

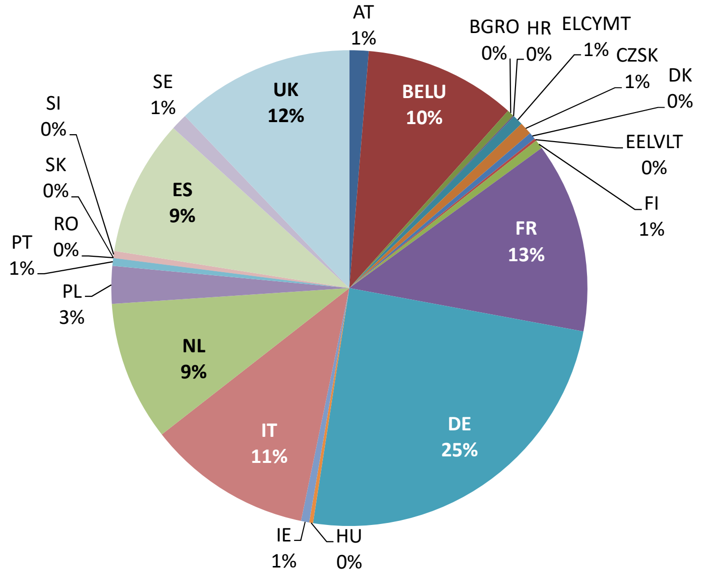
For a more detailed picture with respect to VOC[107] solvents **information on VOC solvent sales by primary producers** was made available (ESIG 2019). The data includes a breakdown of the sales of hydrocarbon and oxygenated solvents made by ESIG member companies[108] by Member State and by type of application (Figure 20-8 and Figure 20-9).

The total volume sold in the EU-28 was 3.8 million tonnes of hydrocarbon and oxygenated VOC solvents in 2017 (3.4 and 3.6 million tonnes in 2015 and 2016, respectively). As it represents the sales within EU-28, export to extra-EU countries is already excluded from these values, while extra-EU import would come in addition (for a discussion on trade see Chapter 20.3).

It can be seen that the MS to which the primary solvent sales are made correspond to the location of the major primary producers as indicated above: one fourth of the sales is made to DE while FR, UK, IT, BE, NL, ES absorb approximately 10 % each.

Figure 20-8 VOC solvent sales by ESIG companies to EU-28 MS (Reference year: 2017)

Total: 3.8 million tonnes*



* Sales of toluene, xylenes, ethanol and methanol not included in this data

Source: Own illustration based on data from ESIG (2019)

The split by application is illustrated in Figure 20-9. It accounts for the sales to the respective sectors (e.g. sale to paint manufacturers, not individual paint use) and distributor sales are allocated correspondingly by ESIG. Some details on the definition

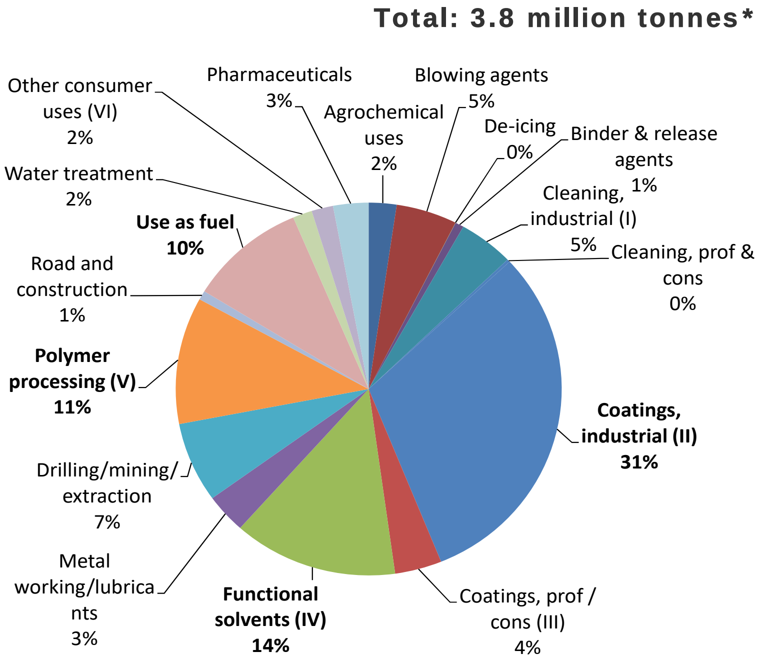
107 As defined by IED (vapour pressure ≥ 0.01 kPa at 20°C).

108 ESIG member companies cover 90-95 % of the EU primary production of the substances included (ESIG 2019).

of the applications are provided in Annex IV based on information from ESIG (ESIG 2019, ESIG 2018d).

For the European average the major VOC solvent sales are effectuated to the coatings sector. Other relevant shares are reported for functional solvents (which partly also go toward intermediate uses)[109], polymer processing and the use as fuel[110]. Following these are solvents used for resource extraction, blowing agents and cleaning solvents.

Figure 20-9 VOC solvent sales by ESIG companies by application (Reference year: 2017)



* Sales of toluene, xylenes, ethanol and methanol not included in this data

Source: Own illustration based on data from ESIG (2019)

Combining the information on the breakdown of sales from Figure 20-8 and Figure 20-9 gives us an idea of which sectors the solvents are sold to in each MS. The result is shown in Figure 20-10. It can be seen that the applications the VOC solvents go toward are quite similar for the different MS. In all major MS except for the BELU[111]-grouping the industrial coatings sector is dominant. In the BELU-grouping the use of solvents as fuel is most pronounced with approx. 30% consumed in this application. No polymer processing sales are reported for IT, while no functional solvent sales are

[109] According to ESIG (2018d) functional solvents include solvents used in chemical processes including intermediates, polymerization and extraction. Solvents used within ESIG member companies (whether intermediate or solvent use) are excluded from the VOC solvents sales data.

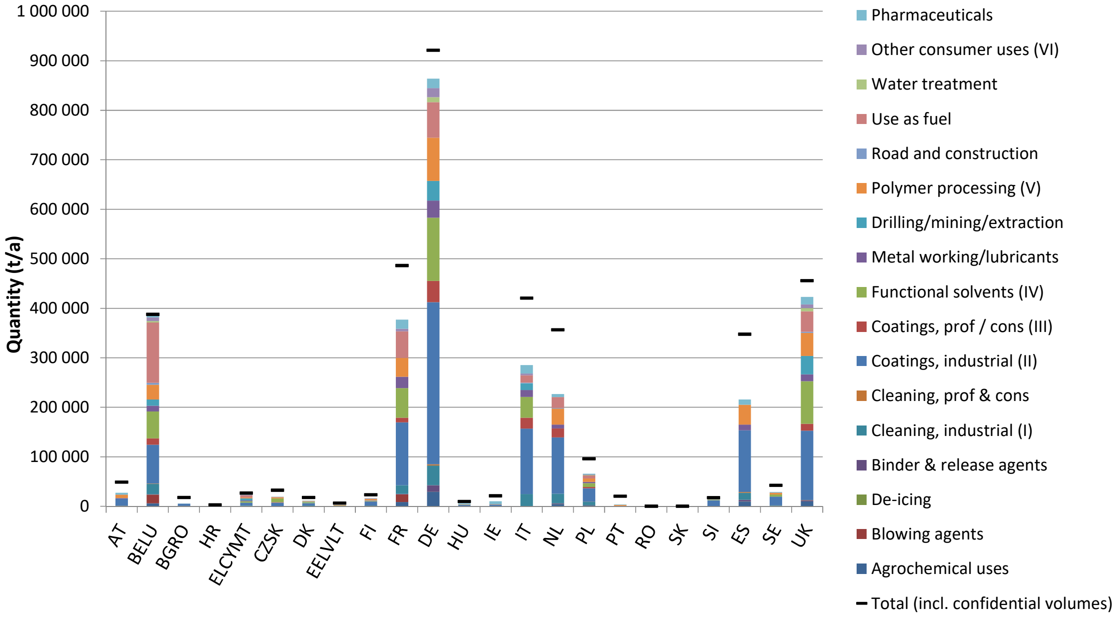
[110] Consumer uses of solvents as fuel exist (e.g. barbeques and lamp oils, lighter fluids, cf. ESIG 2018e), but the major share is industrial use (>90%, ESIG 2019). According to ESIG (2019), hydrocarbon solvents are generally not directly used as fuels (due to excise duty) and also in chemical plants solvents are not normally burnt. Also the use as fuel additives is not the dominant use here (ESIG 2019) and generally uses of organic liquids as transportation fuels (e.g. ethanol or fuel ethers) are not included in solvent uses (see also Chapter 20.1). Within this study no further explanation could be identified.

[111] BELU – aggregate of Belgium and Luxembourg.

reported for NL. The picture is dominated by the seven major producing MS followed by Poland. On average approx. 20 % of the total sales to one MS (or MS grouping for statistical confidentiality) were undisclosed in the VOC solvent sales data provided by ESIG due to confidentiality reasons. This share varies by application: the highest volumes remain undisclosed for blowing agents, oil field/mining chemicals, functional solvents and polymer processing.

For 2016 the picture is very similar while for 2015 more confidentialities are contained due to a different grouping of MS. In general, no data for Greece were available.

Figure 20-10 VOC solvent sales by ESIG companies – combined (Reference year: 2017)



Source: Own illustration based on data from ESIG (2019)

For a comparison of the data on VOC solvent sales described in this chapter and the hydrocarbon and oxygenated solvent quantities presented in Chapter 20.1 it has to be kept in mind that **non-VOC solvents are not included here** (i.e. a fraction of the glycol ethers and the paraffins are excluded). In addition, some important VOC solvents are missing in the ESIG VOC solvent sales data.[112] If the total volume of 5 million tonnes reported by JRC (2019) for hydrocarbon and oxygenated solvents is adjusted accordingly[113], a remainder of 3.9 million tonnes results. This value is comparable to the approx. 3.8 million tonnes[114] reported as VOC solvent sales by ESIG (2019) (see Figure 20-8 to Figure 20-10).

Some uncertainties remain: Comparing Figure 20-9 (VOC solvent sales, this chapter) and Figure 21-1 (for end uses, Chapter 21) it seems that more applications are

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[112] Ethanol, methanol, toluene, xylenes; according to ESIG (2019a) ethanol and methanol are planned to be included in further updates.

[113] I.e. the solvent volumes estimated for ethanol, methanol, toluene, xylenes and 50% of the paraffins (as shown in Table 20-3) are subtracted.

[114] Taking into account that ESIG members account for 95% of the total primary production.

included in the VOC solvent sales presented in this chapter than in those reported for the end uses totaling the approx. 5 million tonnes per year (cf. Chapters 20.1 and 21). The differences in the two different breakdowns by application could not be fully matched. This general uncertainty should be kept in mind when interpreting the available data.

Still the two available breakdowns by application (Figure 20-9 and Figure 21-1) both show that coating activities clearly represent the main end use of solvents.

For chlorinated and nitrogen-containing solvents no overall information on the production by MS was identified. A particular situation exists for the Scandinavian MS (DK, SE, FI), where data on the use of substances in products is published in the SPIN database (SPIN 2019). An illustrative overview is provided in Table 20-5.

Table 20-5 Use of substances in products in DK, SE, FI (chlorinated and nitrogen-containing solvents) – SPIN database (Reference years 2015-2017)

Substance	Volume (kt/a)
DCM	≈0.25
PER	≈0.5
TRI	<< 0.1
NMP	1-3
DMF	0.4-0.8
DMAC, acetonitrile, DMSO	around or below 0.2, each

As expected, these values represent only a small fraction of the volumes identified for the EU-28 (see Chapter 20.1).

20.3 Trade

As commercial goods, solvents or rather the chemical substances which can also be used as solvents are traded between EU Member States (intra-EU) and beyond EU borders (extra-EU). Thus, traded volumes can potentially change the volumes placed on the market in one country compared to the quantities produced. Moreover, trade in the form of solvent-containing products (e.g. paints, inks, cleaning agents) may occur.

To get an impression of the influence of trade on the solvent volumes in Europe the trade in chemicals was first analysed, based on publicly available data from Eurostat. The aspect of trade in solvent-containing products was not covered due to the variety of products and the fact that concrete information on their solvent content would have been required for each case.

Data on the trade of goods are publicly available from Eurostat COMEXT. In the PRODCOM database on sold production[115] Eurostat assigned the COMEXT data to the corresponding PRODCOM entries, thus providing a comparability of the traded flows to the data on production analysed in Chapter 20. The data available in PRODCOM contain extra-EU trade for the EU-28 aggregate as well as extra- and intra-EU trade combined for each Member State (Prodcom 2019). As data for extra-EU trade are reported by customs, these are considered complete. Reporting for intra-EU trade is done by the trading companies and subject to threshold values. This and other limitations lead to uncertainties in internal trade statistics (Comext 2019).

This was also found when evaluating the data reported for the MS: ideally, it would be expected that imports and exports within the EU balance out to a net zero so that summing up the net trade for all 28 MS results in the value reported for the EU-28 aggregate (extra-EU trade). However, this expectation is not met in all cases and in some cases even opposite signs of net trade result.

With respect to the VOC solvent sales to the European MS (cf. Chapter 20.2), an analysis of the extra-EU imports by MS would be of particular interest because it is not included in the data reported by European producers from ESIG (2019). However, no explicit information on the single substances included in the VOC solvent sales aggregate is available and hypothesizing was deemed too uncertain.

It was hence decided to limit the quantitative analysis of trade to the EU-28 aggregate as was done for the production side (Chapter 20.1). For the reference year 2017 the results are shown in Figure 20-11 to Figure 20-13 for the same solvent-relevant substances as included for primary production.[116] It has to be stressed that the volumes **do not directly represent solvent use**. The solvent shares for different substances vary considerably. From negligible shares for, e.g. EDC and benzene (ECSA 2019b, ESIG 2019) to considerable shares for others (see also Chapter 20.1).

Comparing the amounts produced in the EU-28 with the traded volumes for the oxygenated substances shows a **very relevant import for digol, ethyl acetate and methanol**. With > 6 million tonnes the absolute amount of methanol import is very high. Other relevant relative imports can be identified for MIBK, acetic acid, 1-BuOH, other acetates, ethylene glycol, and the THF+ aggregate. Exports are overall less relevant. The highest export compared to EU production was found for other butanols, acyclic ethers, ether alcohols[117] and propylene glycol. For ethanol[118], propanols and acetone relative trade is of minor importance. For 2016 the picture is similar, but some of the imported values are of minor importance (e.g. 1-BuOH, MIBK), while the very high relative import of digol, ethyl acetate and methanol persists. Overall, the volume of imports is approx. 70%, and that of exports approx. 13% of the EU production.

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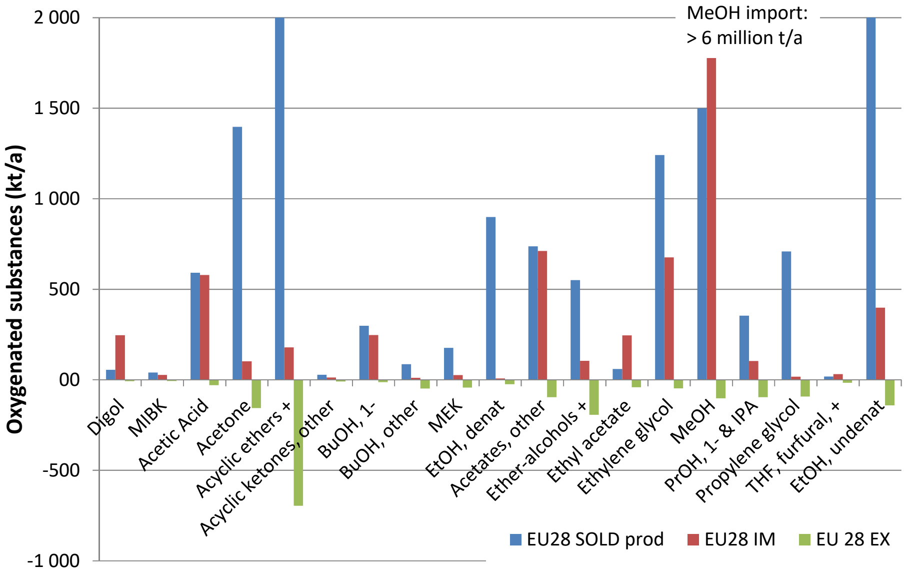
[115] DS-066341: Sold production, exports and imports by PRODCOM list (NACE Rev. 2)

[116] With respect to the trade in solvents the same restrictions as discussed in Chapter 20.1 for production apply: the data for traded substances do not contain any information on the future application (solvent use or other) and in many cases the entries constitute aggregates of several substances, making it difficult to derive conclusions for individual solvents.

[117] Checking with COMEXT revealed that the main share in this aggregate is attributable to cyclic ether alcohols.

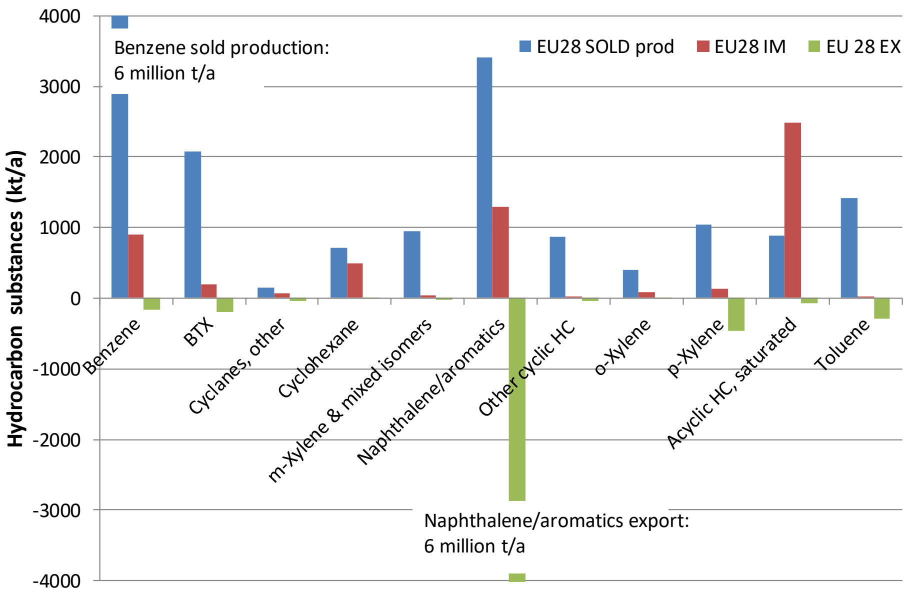
[118] Litres converted to kg with density of ethanol (0.79 kg/L); the minor relevance of trade for ethanol is also confirmed by EC (2019) reporting a net trade < 5% of the amount produced inside the EU.

Figure 20-11 Extra-EU trade in substances with link to oxygenated solvents compared to sold production (PRODCOM DS-066341, reference year 2017)



For hydrocarbon substances the relevance of import compared to internal production is very high for acyclic saturated hydrocarbons and still high for cyclohexane. On the export side, the aggregate of naphthalene and other aromatic HC mixtures shows very high relevance and some relevance of relative export for p-xylene is found. A minor relevance of trade is identified for benzene, other cyclanes, o-xylene, toluene. For BTX, m-Xylene and other cyclic hydrocarbons extra-EU trade does not seem relevant.

Figure 20-12 Extra-EU trade in substances with link to hydrocarbon solvents compared to sold production (PRODCOM DS-066341, reference year 2017)



For 2016 the picture is comparable. Overall, the volume of imports is approx. 30%, and that of exports approx. 40% of the EU production.

For chlorinated substances hardly any import is reported. Export is most relevant for the TRI/PER aggregate and some export for EDC and DCM is reported. Carbon tetrachloride and chloroform are not traded in relevant quantities. Again, the picture for 2016 is similar but the export of TRI/PER is less pronounced.

According to ECSA (2019b) TRI is no longer produced in the EU in relevant quantities, but rather is mainly imported. It is hence estimated that the approx. 20kt reported as import for the TRI/PER aggregate in 2017 are attributable to TRI. In return, the export of approx. 100kt must be attributable to PER (see also discussion in Chapter 20.1).

Figure 20-13 Extra-EU trade in substances with link to chlorinated solvents compared to sold production (PRODCOM DS-066341, reference year 2017)

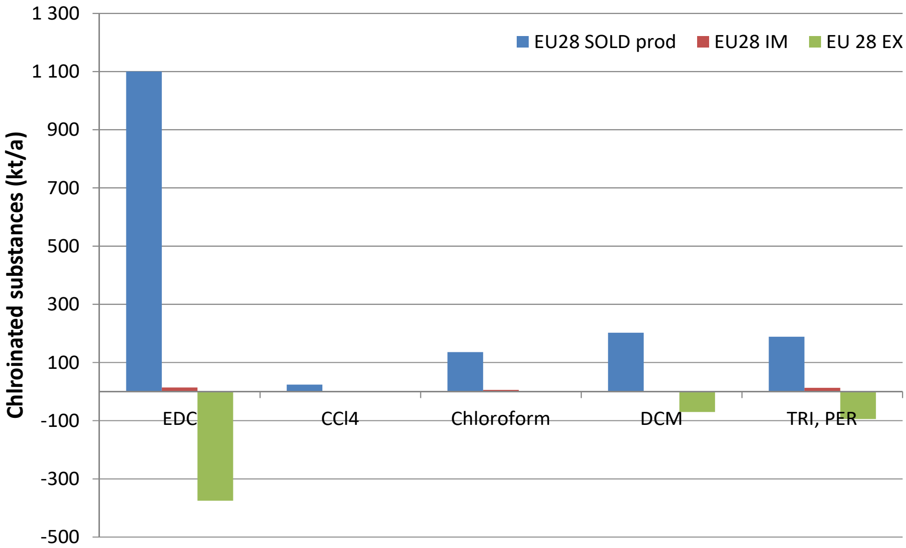


Figure 20-11 to Figure 20-13 show the trade in solvent-relevant chemicals for all uses. In order to derive conclusions with respect to solvents, information on the share going to solvent use is required. An assumption currently also made by ESIG is that the solvent share of traded chemicals equals that of production (ESIG 2019). Based on this an estimate for selected oxygenated substances was derived (see Table 20-6). The solvent shares used are the same as presented in Chapter 20.1.

Table 20-6 Estimate for net extra-EU trade for selected oxygenated solvents - import: positive / export: negative values

Substance	Solvent share	Net trade (chemicals)	Net trade (solvent use)
kt/a	see Ch. 20.1.1	COMEXT/ PRODCOM	derived
MIBK	50%	21	10
Acetone	33%	-53	-20
MEK	90%	-17	-15
Ethyl acetate	90%	204	180
MeOH	5%	6200	300
Propanols	90%	8	7
Total		**6375**	**470**

Glycol ethers and butanols were not included in the analysis because only solvent shares for the combined entries digol/other ether alcohols and 1-butanol/other butanols, respectively, were available. While for digol and 1-butanol considerable imports are reported, there is export of other ether alcohols and other butanols. Reliable conclusions would require information on the solvent share for each entry. Also depending on the solvent shares other relevant contributions might come from acetic acid, other acetates and ethylene glycol (all net imports) or the acyclic ethers aggregate (net export). For ethanol net extra-EU trade is less important (EC 2019).

Based on this approach only limited information can be derived. Nevertheless, it shows that if solvent shares for traded quantities are comparable to those of the local production a considerable net import of solvent ethyl acetate and methanol takes place. Several other entries show relevant net import, too, but more insight into the solvent shares is required.

With respect to hydrocarbon substances no solvent-specific statement could be derived. On the one hand, the major relevance for trade lies with intransparent aggregates, and information on the further use (solvent or not) is lacking. Also for chlorinated solvents information on the solvent shares of DCM and PER was missing but a tendency to net export is observed. Solvent use of EDC is comparably negligible (ECSA 2019b). If all import reported for the TRI/PER aggregate is attributable to TRI, an import of ≈ 4kt for solvent use is estimated for TRI.*

Further solvent-specific analysis requires more detailed insight into the fate of the traded chemicals and also the evaluation of trade in solvent-containing products.

* Based on a solvent share of 20% (ECSA 2019a).

In the context of the solvent VOC inventories (ESIG 2018d, see also Chapter 21) ESIG is also engaged in the analysis of trade. To date the general assumption is that there is no extra-EU net trade in solvents (ESIG 2018d). ESIG (2016), however, mentions a net export of chemicals to Russia and the USA but no further information on the type of chemicals is given. With respect to intra-EU trade substantial export from Belgium, Germany and the Netherlands to other MS is reported for solvents and downstream products (ESIG 2018d). For the UK, France and Ireland net trade is considered zero[119] while the other MS are net importers and assumed to absorb the net exports from BE, DE and NL (ESIG 2018d). Work at ESIG to improve the understanding of solvents trade is on-going also based on direct engagement with the MS. However, to date no data on the traded volumes of solvents and solvent-containing products has been made public.

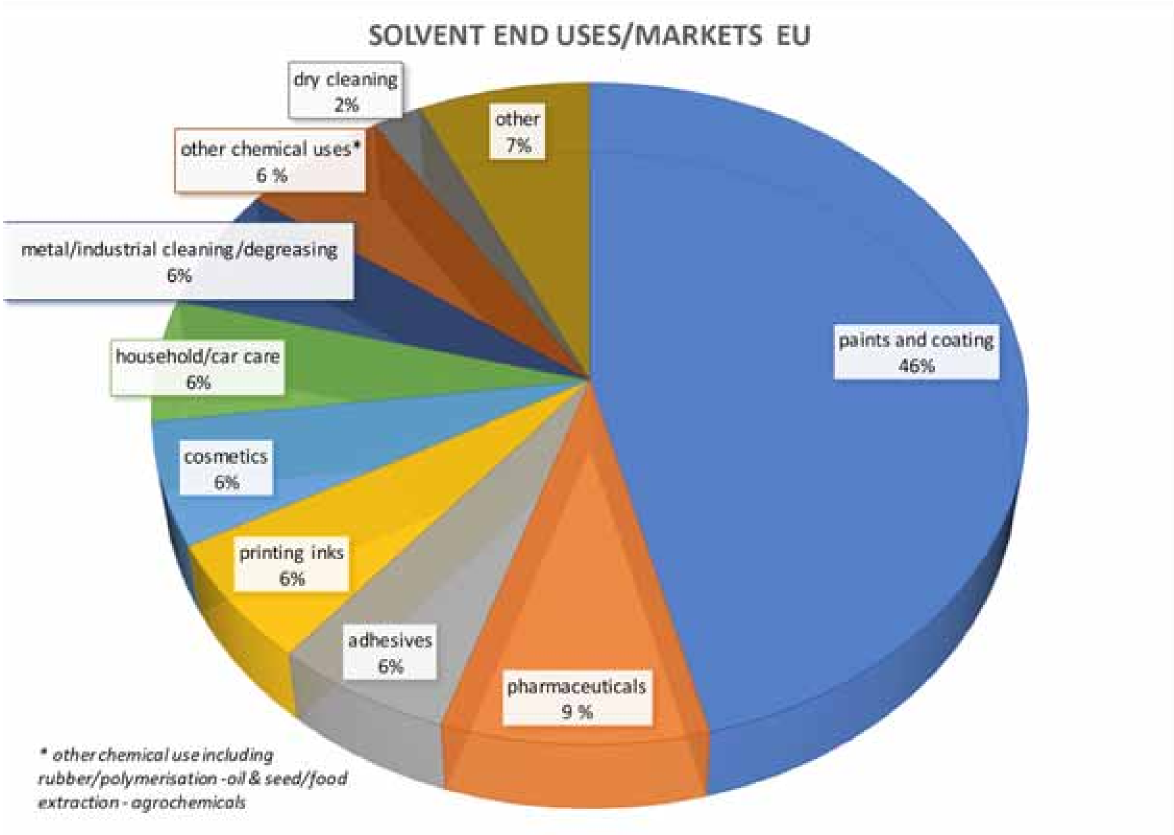
[119] For Ireland this is remarkable because the Irish pharmaceutical industry imports all solvents needed for their activities (CTC 2010). In general, solvents used in the manufacture of pharmaceutical arise as waste. Spent solvents are mostly exported from Ireland (CTC 2010).

21 Use of solvents and emissions to air

In general, solvents are chosen for use in an application based on their specific physio-chemical properties so that different substances/mixtures can be used in one application and different applications may use the same solvent. If "solvent" use is related to applications on an aggregated level the direct notion of the substances involved is lost (see also Chapter 19.2). With respect to the material flow analysis this represents an important break because the volumes of the single substances identified in Chapter 20 cannot be directly traced to their final fate (also for the waste stage solvents are identified by their origin / the application they were being used in, see Chapter 22).

Figure 21-1 shows the shares of typical end uses of solvents based on data provided by ESIG (ESIG 2019). The underlying total volume is approx. 5 million tonnes of hydrocarbon and oxygenated solvents (JRC 2019).

Figure 21-1 Solvent end uses in the EU



Source: ESIG (2019)

Please note that this figure refers to end uses and does not include the use of solvents in the manufacture of chemicals.

Comparing to JRC (2009) this pattern seems to have remained essentially unchanged over the last 10 years. The breakdown by applications provided for the VOC solvent sales additionally specifies other applications like the use as functional solvent in chemical processes (e.g. as reaction medium in organic syntheses, or as an extraction agent for downstream product purification), the use as blowing agents for polymer foams, or applications in metal working, mining, and de-icing (see Chapter 20.2). Also the industrial use as fuel is included there, although it is not generally a solvent use because in the application itself the solvent is combusted. As explained in Chapter 20.2 the differences could not fully be matched.

Solvents are generally used as an auxiliary in the process or service to be delivered and meant to separate from the product/treated object after having accomplished their function. The accumulation of solvents in long-term articles is negligible (Smallwood 2002). This means that the solvent volumes entering the use phase during/after use are emitted in waste flows (whether evaporated or as liquid waste).[120] A change in stock may occur in the form of stocking of solvent-containing products (before use) or changing production capacities with, e.g. varying reaction volumes. Such variations were not considered in the present study.

Solvent losses to air during use

The quantities of solvents released to air compared to those recoverable as liquids after use depend on the application and the volatility of the solvents. While, e.g. in the chemical and pharmaceutical industries solvent waste predominantly arises in liquid form, in coating applications (paints, inks, adhesives) the solvents are intended to evaporate and leave the dry coating in place. Liquid spent solvent may only arise from cleaning of the equipment, residual product, or when solvent is recovered from off-gas.

This chapter focusses on the emissions of solvents into the air during the use phase which result in losses to the material flows recoverable at end-of-life. The waste stage of liquid solvents as well as the possibility to recover solvents as liquids from captured off-gas are discussed in Chapter 22 and 24.

As VOC[121] emissions are of environmental concern due to their contribution to ground-level ozone, these have to be monitored and reported under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). This reporting gives access to data for the estimation of solvent losses in the use phase (CEIP 2019). Beside the national reporting, the industry association ESIG prepares dedicated solvent VOC emission inventories (ESIG 2018d).

It has to be kept in mind that both inventories report solvent emissions as VOC. In many industrial and some professional applications capture systems for solvent-laden off-gases are operated where often the VOC content is oxidised in order to reduce VOC emissions to the atmosphere.[122] After oxidation the solvent is released into the air as CO_2 which constitutes an additional loss to the material cycle.

The data from the CLRTAP reporting are shown in Figure 21-2 for each Member State for the reference year 2015 for comparison. For 2017 CLRTAP data are overall slightly higher but very similar. Figure 21-3 gives the trend for the EU-28, estimated by the national reporting for 2014 to 2017 showing an unchanged picture over the last four years.

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[120] In some applications on-site recycling of solvents is practised. This in parallel reduces the net solvent requirements as well as the waste streams emitted from the process.

[121] Volatile organic compounds; as described in Chapters 19.2, 20.2 and this chapter many solvents are VOC and evaporate during application or subsequent drying.

[122] Oxidation refers to the destruction of solvents in the off-gas by oxidation to CO_2 and water. It is practiced in many applications which are subject to the IED in order to comply with VOC emission limits. A description of different techniques can be found in JRC (2019).

Guidance on the elaboration of the national emission inventories is available via the EMEP/EEA air pollutant emission inventory guidebook (EEA 2016/2019) and specific documentation for each MS can be found in the Informative Inventory Reports (IIR; CEIP 2019).

While the EMEP/EEA emission inventories provide data for several key air pollutants from many industrial activities, for this evaluation the NMVOC-emissions reported for the category E_solvents[123] were analysed. Moreover, codes from the category B_industry[124] and L_agriother[125] were included, where solvent emissions might occur (chemical industry: other, storage/handling/transport, wood processing, pesticide use) to check for a possible contribution. In general, the NMVOC emissions from the category E_solvents make up >90 % of the NMVOC emissions from the categories analysed (values see black bar in Figure 21-2[126]). The contribution of wood processing to NMVOC is very small, if any. For the selected codes of L_agriother none of the MS reports any NMVOC emissions.

The total NMVOC emissions for EU-28 amount to approx. 2.6 million t/a (E_solvents only) and 2.7 million t/a (E_solvents plus selected B_industry).

Figure 21-2 and Figure 21-3 show that in general the main contribution to solvent-related NMVOC emissions comes from coatings. Domestic solvent use plays an important role, too.[127] Next, chemical products, printing and degreasing appear. The highest emissions are reported for Germany with 550kt/a, followed by FR, IT and UK (all just above 300kt/a), Spain and Poland. All other MS report emissions below 100kt/a, in many cases considerably lower.

[123] Incl. NFR codes 2D3a Domestic solvent use, 2D3d Coating, 2D3e Degreasing, 2D3f Dry cleaning, 2D3g Chemical products, 2D3h Printing, 2D3i Other solvent use and 2G Other product use (see CEIP 2019, EEA 2016/2019)

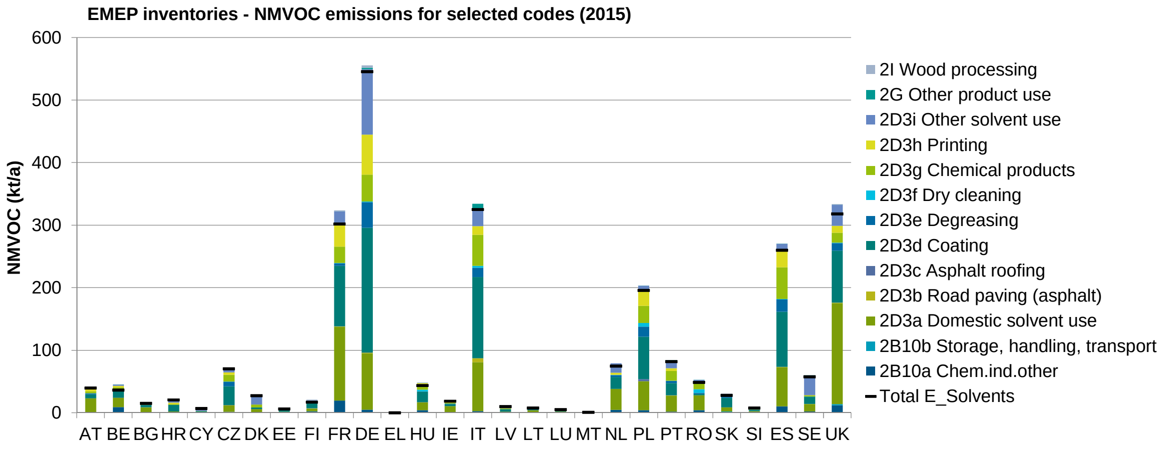
[124] NFR codes 2B10a Chemical industry other, 2B10b Storage, handling, transport of chemical products, 2D3b Road paving (asphalt), 2D3c Asphalt roofing, 2I Wood processing (see CEIP 2019, EEA 2016/2019)

[125] NFR codes 3Da2c Other organic fertilisers, 3Df Pesticide use (see CEIP 2019, EEA 2016/2019)

[126] For BE and FI values somewhat lower mainly due to reporting under "chemical industry: other"

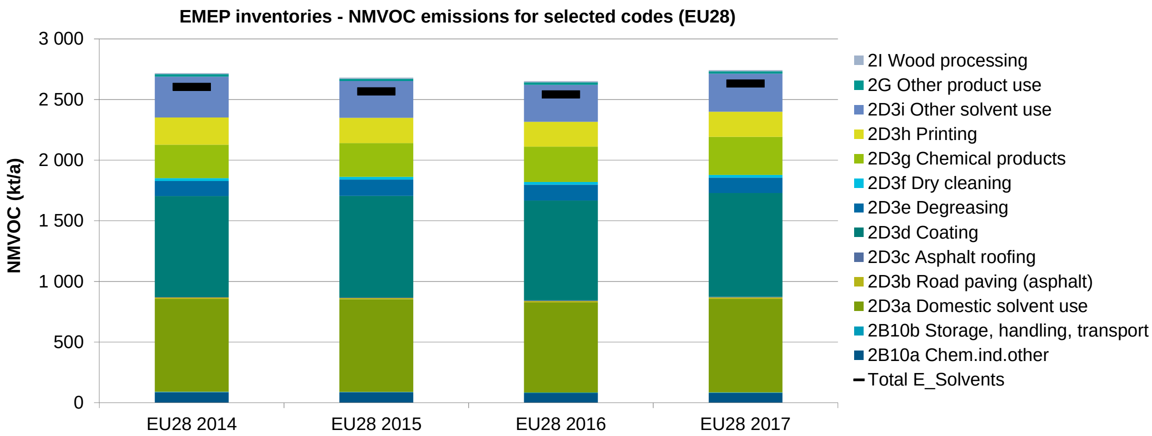
[127] According to EEA 2016 domestic use of decorative paints is not part of the Chapter 2.D.3.a `Domestic use´ but covered in Chapter 2.D.3.d 'Coating application'. The main categories for domestic use include: cosmetics and toiletries, household products, construction/DIY (paint remover and adhesives included), car care products, pesticides (excl. professional agricultural use), pharmaceutical products. Moreover, in cases where a distinction between domestic and industrial/professional use cannot be made emissions should be attributed to domestic use.

Figure 21-2 Solvent VOC emissions in Europe (Reference year 2015; CEIP 2019)



No data available for Greece

Figure 21-3 Development of solvent VOC emissions in Europe (CEIP 2019)

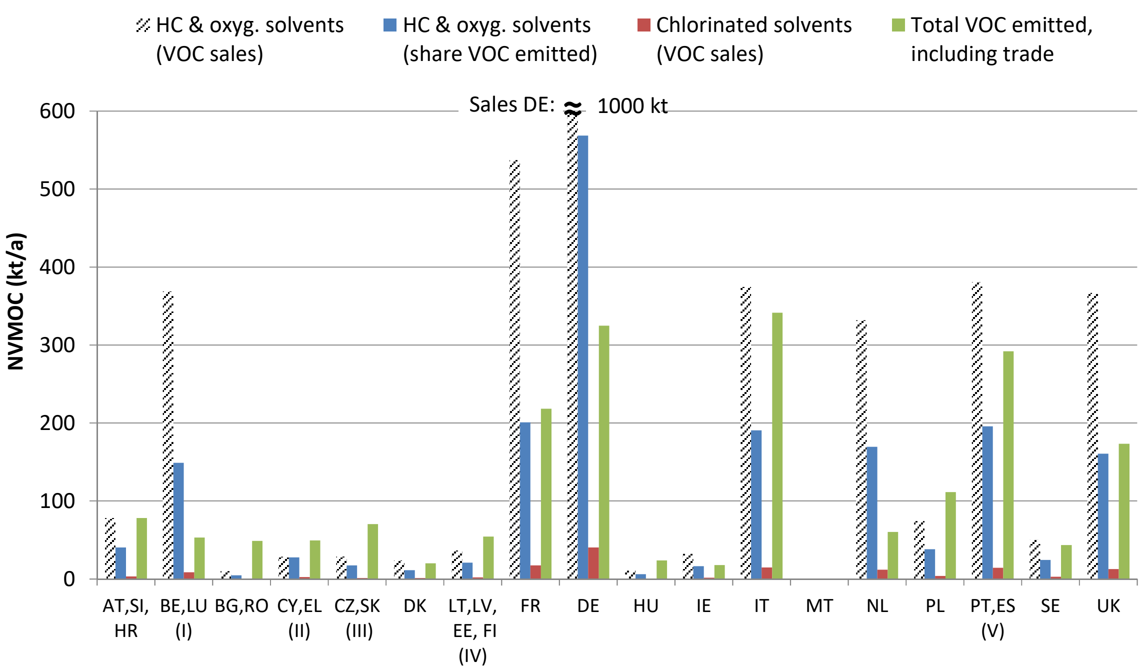


No data available for Greece

The ESIG solvent VOC emission inventories are based on the solvent volumes sold to each application multiplied by a corresponding release-to-air (rta-) ratio. This rta-ratio represents the fraction of the volume of solvent released-to-air as NMVOC divided by the volume entering the application. The basis for the latter are the VOC solvent sales presented in Chapter 20.2. The industry estimates for the rta-ratios by application are included in Annex IV based on ESIG (2018d). While for consumer applications in general a complete release of VOC solvents to the atmosphere is assumed, the rta-ratio may be lower for industrial and professional uses where capture systems are operated. For industrial coatings, where in general legal requirements prescribe the use of VOC abatement techniques for the off-gas (IED), ESIG (2018d) suggests a rta-ratio of 10%. However, for calculating the VOC emissions for the inventory a rather high average rta-ratio is applied for household, professional and industrial use (75 %). While this may overestimate the actual VOC emissions resulting from industrial coatings, it may be seen as an approximation of the large losses to air from this important field of application – if not as VOC then as CO_2 after oxidation. As solvent recovery from solvent-laden off-gas today is still rather limited (see Chapter 24.2), it is possible that overall losses are even higher.

The result of the ESIG emission estimates is shown in Figure 21-4 for 2015.

Figure 21-4 Solvent VOC emissions in the Member States in 2015 (ESIG 2018d); values for VOC solvent sales (ESIG 2019)



(I) BE, LU sales value for 2016
(II) No data available for Greece
(III) VOC solvent sales value only for CZ (28kt); in 2016 SK incl. in sales aggregate yielding a total of 26kt
(IV) VOC solvent sales value for LT, LV, EE for 2016; FI 78% of total sales
(V) The PT/ES-aggregate (Total incl. trade) can be separated into 272kt (ES) and 20kt (PT).

The blue columns show the emission estimates for each country in comparison to the solvent sales effectuated to the respective MS (dashed columns). As also shown in Chapter 20.2, especially Belgium, France, Germany, Italy, the Netherlands, Spain[128] and the UK absorb the solvent sales from primary production. Including an estimate for intra-European trade in solvents and solvent-containing products, the actual emissions of each MS are corrected to represent only the emissions based on the national consumption (green columns[129]). According to ESIG (2018d) Belgium, Germany and the Netherlands are substantial exporters of solvents and downstream products; the UK, France and Ireland are balanced, while the remaining Member States are net importers (see also Chapter 20.3).

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[128] Spain is by far the major partner in the PT/ES aggregate (> 90 % based on ESIG 2019).

[129] The green value also contains the chlorinated solvents which were calculated as 100% emitted in a simplifying manner (ESIG 2018d). In reality, capture systems are operated in particular for many applications using chlorinated solvents so that the majority is emitted as CO_2 (ECSA 2019b).

Comparing the VOC emissions for HC and oxygenated solvents (blue columns, excl. trade) with the VOC solvents put on the market in each country (dashed columns, see Chapter 20.2) it can be seen that approx. 50 % are estimated to be released into the air as VOC.[130] This observation is rather stable throughout the MS indicating similar usage patterns. A lower value of approx. 40 % is found for France and BE[131] which can be explained by comparably high uses as fuel (full emission as CO_2), functional solvents and in polymer processing which all have low rta-ratios.

In comparison to the results of the EMEP/EEA emission inventories, it can be seen that the values from the ESIG solvent VOC inventories are considerably lower in many cases (e.g. DE, UK, FR) and in other cases the agreement is good (e.g. IT, ES, NL).

Overall, approximately 2.6-2.7 million t/a of solvents are reported as NMVOC emissions by the national inventories (EMEP/EEA, CEIP 2019). According to ESIG (2018d) approximately 2 million t/a of solvents are emitted into the air. On the one hand, ESIG (2018d) states that in most national inventories the emissions are based on industrial activity multiplied by a general factor. On the other hand, some solvents (e.g. ethanol, methanol, toluene and xylenes) are not yet included in the ESIG inventories (ESIG 2019).

Despite the uncertainties it may roughly be concluded that approx. 50 % of the solvents placed on the market are emitted into the air. The losses may be higher if emission of solvents to air after abatement as CO_2 is included.

[130] Trade is not relevant in this comparison because the rta-ratios are not MS-specific so that even if solvents are traded to another MS the emissions occur (elsewhere) entailing losses to the material cycle. For the chlorinated solvents, the ESIG VOC inventories calculated in a simplifying approach that they are fully emitted into the air (ESIG 2018d). In reality they are generally used in closed systems and not released into the air without treatment (ECSA 2019b). Overall due to the much lower volumes their contribution is comparably negligible.

[131] For BE using VOC solvent sales for the reference year 2016

22 Waste generation and treatment

Solvents which are not evaporated and released into the air[132] during operation at some point become liquid waste because contamination occurred during their application. Contamination may result from mixture with air, water, a solute (dissolved components when used as a carrier, e.g. in reactions or cleaning operations), or with other solvents (JRC 2018, Smallwood 2002). Other reasons may be the mixture with particles (e.g. swarf), an alteration of the originally specified composition of a mixture due to partial evaporation, the chemical degradation of a preparation (e.g. paints, varnish, adhesives) as well as simply unusable residual quantities (Martens/Goldmann 2016).

With respect to the treatment of used solvents and other hazardous organic liquids two situations need to be differentiated: **internal treatment**, where the utilizing company itself operates equipment to collect and regenerate a solvent on-site in order to utilize it again in its operations (or on-site utilization of its calorific value); and **external treatment**, where spent solvents are transferred to external waste operators due to economical and/or technical considerations (e.g. quantity of spent solvent or degree of contamination).

Internal recycling is practised in large volumes in the producing chemical industry and also to some extent in the pharmaceutical industry. In the coatings sector mainly the liquids used for cleaning the equipment may be regenerated on-site (FPE 2019, JRC 2019). With respect to the recovery of solvents contained in the coatings, publication rotogravure is an outstanding example, where > 95 % of the toluene contained in the ink is recovered on-site and directly reused or delivered back to the ink maker (JRC 2019). For coil coating processes, JRC (2019) reports that solvents from waste paints are commonly recovered and reused for cleaning purposes.

In general, data on the amount of solvents recycled and reused on-site is difficult to access because these volumes are potentially not covered by statistics.[133] With respect to the overall material balance, on-site recycling can be omitted in the sense that from a global perspective it simultaneously decreases net solvent input and waste output. On-site recycling was hence generally excluded from the quantitative analysis in this study with the exception of those cases where volumes recycled on-site are included in Eurostat data on waste[134].

The situation for on-site energetic use of spent solvents (e.g. in CHP plants in the chemical industry) is different. Here, the on-site use does not lead to decreased solvent input. Also Eurostat (2013) stipulates that on-site energetic use should be

[132] directly or as CO_2 after abatement

[133] Experiences from treatment of other wastes have shown that this aspect is not treated uniformly in the Member States. Also CTC (2010) found that for the case of spent solvents in Ireland this was only partially true, with some companies also reporting internally recycled volumes. In order to obtain information on internally recycled quantities for this study a questionnaire was issued to ESVOC members (European associations representing downstream users of solvents). However, at the level of these EU associations no data could be made available concerning waste generation and internal or external handling. In general, most internal recycling occurs within the chemical industry which is not an ESVOC member, but rather producer itself. The pharma industry is also not an ESVOC member. ESVOC member associations include mainly downstream users from the coatings sector, a list can be found on: https://www.esig.org/wp-content/uploads/2019/04/ESVOC_who_what_2019.pdf, last access: 19/10/10

[134] There is no way of differentiating these cases from the total values indicated by Eurostat.

included in official waste statistics but it is not certain to what extent it is covered in actual reporting.

The quantitative evaluation of solvent-related waste streams is based on Eurostat waste statistics. This information was amended by national data gathered from a survey among national administrations (MS survey 2019).

Eurostat statistics provide aggregated information by waste categories as defined in the Waste Statistics Regulation (WStatR). Each waste category combines defined entries of the List of Waste (LoW). For spent solvents a dedicated category exists (01.1). It includes the major LoW codes directly referring to the generation of spent solvents (from LoW chapters 07, 14 and 20). Other origins (especially paint and varnish, ink and adhesives) which generate solvent-containing waste are excluded.[135]

For the category 01.1 "spent solvents" two Eurostat datasets were analysed:

- Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (env_wasgen) (see Chapter 22.1)
- Treatment of waste by waste category, hazardousness and waste management operations (env_wastrt) (see Chapter 22.2)

Information on waste generation and treatment from additional codes (in particular from coatings, degreasing wastes, antifreeze and brake fluids) was targeted via the MS survey. The survey also included the LoW codes for spent solvents already available as aggregate from category 01.1. The differentiation by entry targeted disagreggated information on the origin and type of the spent solvents (e.g. halogenated/ non-halogenated, relevance of refrigerants and solvent-containing sludges/ solids). An overview of the relevant chapters is given in Table 22-1. A detailed list of the LoW entries included can be found in Annex V.

[135] LoW entries "containing solvents" from other origins, as well as entries referring to the generation of other hazardous liquid organic chemical wastes are grouped in other statistical categories (cf. WStatR). There, however, they are combined with other types of waste (e.g. solid and/or inorganic) so that no dedicated evaluation is possible.

Table 22-1 Overview of relevant LoW Chapters

LoW Chapt.	Title	Included activities/substances
03	Wastes from wood processing and production of panels, furniture, pulp, paper, cardboard	organic wood preservatives
04	Wastes from the leather, fur and textile industries	textile finishing wastes containing organic solvents
07	Wastes from organic chemical processes	MFSU of basic & fine organic chemicals, pharmaceuticals, plastics, synthetic rubber & fibres, organic dyes/pigments, detergents/disinfectants/cosmetics, agrochemicals/biocides,
08	Wastes from MFSU[136] of coatings, adhesives, sealants and printing inks	MFSU of paints, varnishes adhesives, sealants, printing inks
11	Wastes from chemical surface treatment and coating of metals and other materials; non-ferrous hydrometall.	degreasing wastes,
14	Waste organic solvents, refrigerants and propellants (except 07 & 08)	chlorofluorocarbons/HCFC/HFC; other solvents/-mixtures; solvent-containing sludges or solids
16	Wastes not otherwise specified in the list	brake fluids, antifreeze fluids
20	Municipal wastes incl. separately collected fractions	solvents; paint/inks/adhesives/resins containing hazardous substances

In addition to the information related to spent solvents and solvent-containing wastes, selected codes referring to other hazardous liquid organic waste were included. This mainly involved hazardous liquid waste streams from organic chemical processes (LoW Chapter 07: still bottoms and reaction residues). These may also contain solvents and are sometimes accepted by solvent recyclers[137], but their relevance to solvent recyclers is lower than that of the dedicated solvent entries in the same chapter ESRG (2019).[138] Moreover, several hazardous entries potentially referring to liquid organic wastes in LoW Chapter 16 (e.g. from off-specification batches, unused products, laboratory chemicals, wastes from tank and barrel cleaning) were included, see Annex V. These entries are, however, unspecific with respect to composition (liquid/solid and in some cases organic/inorganic).

[136] MFSU = manufacture, formulation, supply and use

[137] See e.g. https://www.resolve.de/fileadmin/user_upload/resolve/downloads/zertifikate_2019/efb-zertifikat_remondis_medison_gmbh_braunschweig.pdf, last access: 19/10/11;
MS survey (SK)

[138] The evaluation by HWE (2019) revealed 3% going to R2 treatment for only one corresponding LoW code (070108*).

22.1 Generation of spent solvents and other hazardous organic liquids

The spent solvent quantities generated throughout Europe are shown in Figure 22-1 for the spent solvent streams included in WStatR category 01.1. In total a value of 2.4 million t/a of spent solvents is reported for the EU-28. This volume also includes contaminants (e.g. water, solutes, particles). The overall average solvent content of the spent solvent streams is unknown.[139] Grossly estimating the solvent content based on the average yield of solvent recycling of 75 % reported by ESRG (2019) would result in at least 1.8 million t/a of solvents contained in the waste.[140]

It has to be kept in mind that data on generation also include spent solvents generated by the chemical industry. The solvents used in the chemical industry are, however, probably not fully included in the amount of solvents used in end uses as described above (approx. 5 million t/a, see Chapters 20 and 21).

Figure 22-1 Spent solvents generated in EU-28 (Category 01.1, Eurostat: env_wasgen)

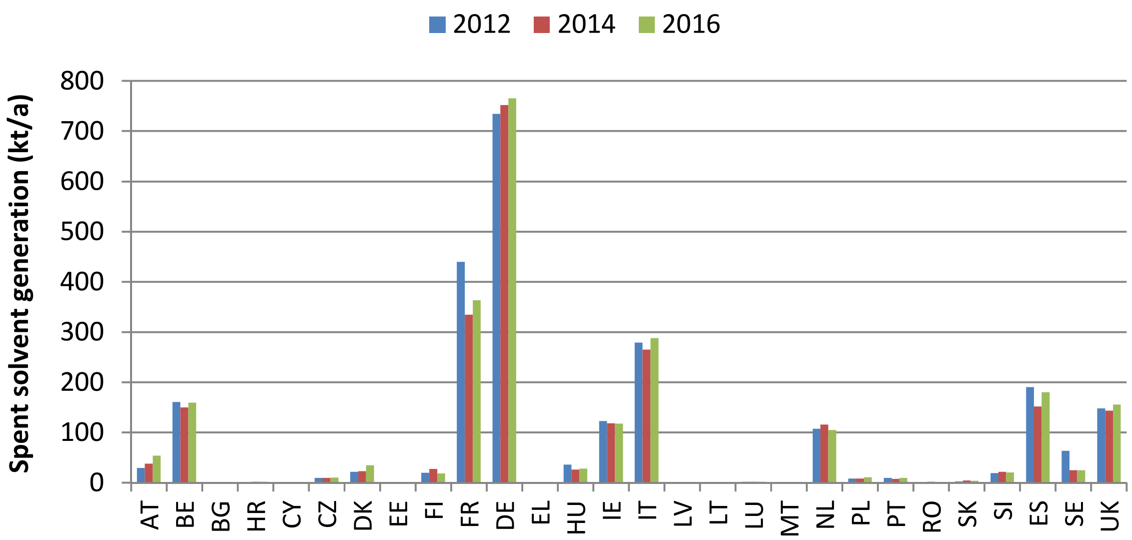

Figure 22-1 shows that by far the largest volumes are generated in Germany, France and Italy. With > 700kt/a of spent solvents Germany produces one third of the total spent solvents generated in Europe. As expected, the seven MS already identified as major producers/users of solvents (BE, FR, DE, IT, NL, ES, UK; cf. Chapters 20.2 and 21) generate high waste volumes. In addition, Ireland reports a value > 100kt/a.

[139] E.g. the German database ABANDA offers data on composition by LoW code based on waste analyses. For solvent-relevant LoW codes, however, the variability of the composition compared to the number of samples appears much too high to allow general conclusions to be made (Abanda 2018). Also BDSAV (2019) confirmed that it is not possible to make a general statement with respect to the composition of spent solvent streams based on the LoW code.

[140] The yield is defined as kg_solvent,recovered/kg_waste-input. Given that some residual solvent may be left in the waste after recycling, the solvent content is in general higher than the yield. The content may, on the other hand, also be lower than the actual average yield from recycling because the presented volumes refer to waste generation of which some quantities are treated by incineration. Using the average yield from spent solvents going to recycling only is probably too hypothetical.

The high value for IE is explained by the fact that pharmaceutical industry is very active there. According to CTC (2010) this industry generates >95 % of the Irish solvent waste. While CTC (2010) anticipated the waste volumes to decline, the quantity reported today is still at the same level as in 2007 (110-120kt).[141]

> The generation of these 8* MS covers 91% of the total generation. 14 MS** report volumes of around 10kt/a or less (together ≈2% of total generation). AT, DK, FI, HU and SE lie in between and account for the remainder.

* BE, FR, DE, IT, NL, ES, UK and IE

** BG, HR, CY, **CZ**, EE, EL, LV, LT, LU, MT, **PL**, **PT**, RO, SK (CZ, PT, PL around 10kt/a)

For the reference year 2016 Figure 22-2 shows that on European average approx. ¾ of the volume in the category "spent solvents" are generated in the manufacture of chemical, pharmaceutical, rubber and plastic products. This figure varies by Member State, with 17 MS reporting two thirds or more, 6 MS[142] reporting between 33% and 66%, and 5 MS[143] reporting one third or less, giving an indication of differing industrial structures in the respective MS. Except for the values for HR, CY and MT, a tendency shows that lower overall volumes (Figure 22-1) correspond to a lower contribution from the chemicals, pharmaceutical, rubber and plastics sector (Figure 22-2, MS reporting < 66%). The next biggest contribution to European spent solvent generation is from operations related to waste handling, a value which is dominated by BE, FR, DE, PT, ES – all countries with solvent-producing industry.[144] Households, in general, contribute very small shares throughout Europe, with the exception of LV which reports between 30-50%. However, the national reply to the survey indicates that also for Lativa only 20% (14%) of the spent solvents come from households (LoW code 200113*), while 75% (81%) are reported for manufacturing activities in organic chemical processes (LoW Chapter 07) for the year 2016 (2017 values in parentheses) (MS survey 2019). For other manufacturing, "basic metals" contribute in BG, CY, SK and "computer and electronics" especially in BG, RO and SK, but also in CZ, HU, LT and PL. "Paper" reaches relevant shares in BG, EL, LT, RO.

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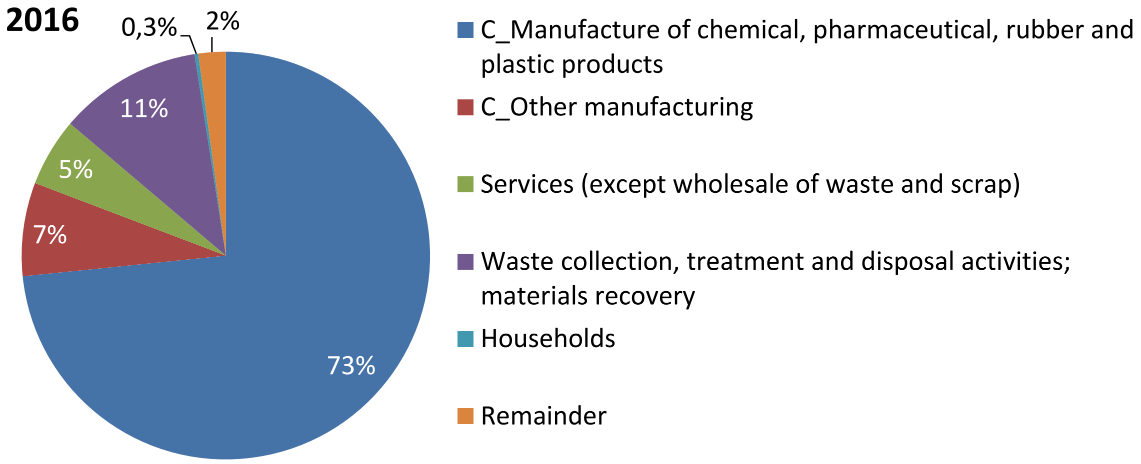
[141] In addition, an on-site recycling of approx. 40kt is reported at the time (CTC 2010).

[142] CZ, EE, LV, LU, PL, PT; for Portugal, according to the national reply to the questionnaire >80% of the spent solvents in category 01.1 are from LoW codes 07 xx 03* and 07 xx 04* (MS survey 2019)

[143] BG, EL, LT, RO, SK

[144] Note: According to Eurostat WStatR metadata the data on generation of waste include the wastes produced by the waste treatment activities applied to the respective LoW codes.

Figure 22-2 Origin of spent solvents by NACE code (Category 01.1, Eurostat: env_wasgen)



No differentiation according to type of substance / solvent subgroup is available from the public Eurostat data (aggregate of the LoW codes from WStatR Category 01.1). Also the reporting by LoW codes only differentiates by origin (type of industrial activity generating the waste) and in very broad terms by physicochemical properties (e.g. between halogenated and non-halogenated waste or between liquid residues and solids/sludges).

In response to the MS survey, six Member States provided data on waste generation by LoW codes (CZ, DK, EE, HR, LV, PT).[145] In addition, national statistics on waste generation and treatment were evaluated for Germany (Destatis 2016). The evaluated contributions represent approx. one third of the total EU-28 waste generation, and in terms of volume are vastly dominated by Germany (93% of the evaluated contributions).

A comparison of the data from the national contributions and Eurostat is included in Annex VI. With respect to generation the same data are reported for DK, EE and HR. For CZ and DE the agreement is reasonably good. For Portugal the spent solvent generation reported by the MS survey (2019) is nearly twice as high.

i. Origin of volumes reported under Category 01.1

The category is dominated by entries for non-halogenated solvents (≥ 66% in all cases). A relevant fraction is reported under halogenated solvents in CZ, DE and PT. Sludges represent a small share (in general <5%). Also spent solvents from households are comparably negligible (a comparably high value of 20% is reported for LV). Hardly any chlorofluoro(hydro)carbons (140601*) are reported. The waste streams from LoW Chapter 07 (various organic chemical processes) dominate the generation ranging from 2/3 (CZ, EE) and ¾ (HR, LV) to > 80% (DE, PT).[146]

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[145] More MS submitted answers (BE, ES, SK) but no data by LoW codes were included.

[146] Based on a relevance threshold of 10% the contribution is considerable for:
- pharmaceutical industry for all MS except EE (PT halogenated)
- basic organic chemicals in CZ, DE, and EE (CZ halogenated)
- fine chemicals in DK, and LV (LV halogenated)
- organic plant protection in DE (halogenated)
- other non-halogenated waste solvents (140603*) for CZ, DE, EE, HR, PT (CZ 32%).

Together the seven MS[147] included in this evaluation report a generation of halogenated spent solvents of 210kt[148]. Compared to this, the total primary production of the major chlorinated solvent substances (DCM and PER) in Europe is below 400 kt/a, and a significant share seems to be exported or used as chemical intermediate (see Chapter 20.1 and 20.3). For 2013, ESIG (2018d) reports a chlorinated solvent use of approx. 140 kt/a. As several MS with high spent solvent generation and chlorinated solvents put on the market (cf. Figure 21-4) are not included in the above value of 210kt halogenated spent solvents (e.g. FR, IT, ES, UK, BE), the reported volume seems comparably high. An explanation may be that spent solvent streams containing only minor concentrations of chlorinated solvents are also reported under "halogenated" (e.g. contaminated after a change of batch). Another reason may be the presence of other substances, e.g. water.

ii. Volumes of other LoW entries referring to solvents-containing waste and other hazardous liquid organic chemicals as identified in this study (cf. Table 22-1, Annex V)

The waste volume generated and the respective shares for each category are shown in Table 22-2. The LoW codes included in each category are described in Annex V. The information on Cat. 01.1 spent solvents is included for comparison. Germany accounts for nearly 90 % in terms of volumes for the contributions shown.

Table 22-2 Waste generation referring to spent solvents and other hazardous organic liquids in the evaluated contributions to the MS survey (2019)

Reference year: 2016	CZ	DE	DK	EE	HR	LV	PT
Total generation (kt)	**70**	**1343**	**61**	**6**	**5**	**0.6**	**32**
Category 01.1 Spent solvents	16%	50%	56%	7%	38%	47%	56%
LoW 08 containing solvents	38%	14%	24%	58%	55%	50%	25%
Other LoW containing solvents	19%	4%	2%	2%	4%	3%	3%
Still bottoms & reaction residues (LoW 07)	22%	29%	6%	33%	3%	0%	16%
Other chemical wastes (LoW 16)	6%	3%	13%	n.r.	n.r.	n.r.	n.r.

DE, DK and PT report the major volumes for the Category 01.1 Spent solvents. For CZ, EE, HR and LV the volumes reported under LoW Chapter 08 are more important. However, it has to be taken into consideration that for Category 01.1 the entries directly refer to waste solvents. In LoW Chapter 08 the solvent contents in the waste are certainly smaller for many entries. The main contribution in this category is generally from waste paint: if, e.g. a solvent content of 30% is assumed, the volumes decrease by a factor of three.[149] The volumes for other solvent-containing LoW entries are comparably small. In particular, the entries referring to wastes from wood preservatives and textile finishing (LoW Chapters 03 and 04) are reported to be zero

[147] CZ, DK, EE, HR, LV, PT and DE

[148] DE: 204kt in 2016 (Destatis 2016)

[149] For illustrative purposes; assuming solvent contents of 30% for waste paint, inks and adhesives (industry & households), 5% for paint sludges (Martens/Goldmann 2016), 35% for ink sludges (Tebert (2019) for sludges from heatset web off-set printing), 35% for adhesive sludges (set same value as for ink sludges) and 90% for wastes from paint removal and waste paint remover (Martens/Goldmann 2016).

or comparably negligible for all MS. With the exception of DE, brake fluids also constitute a small share. For CZ a relevant contribution is due to degreasing wastes which in absolute terms are reported to be in the same order of magnitude as for DE. Considerable quantities for still bottoms and reaction residues are reported for CZ, DE and EE. For CZ and EE their contribution is higher than that of Category 01.1 Spent solvents but the absolute quantities are largely dominated by DE (> 90%, distributed across different industrial activities). Other chemical wastes seem to be of minor importance.[150]

Due to the limited number of responses to the MS survey and the difficulty of assigning an average solvent content to the solvent-containing streams in question, no quantitative conclusion concerning the spent solvent volumes recorded under the additional LoW codes can be made on EU-28 level. It is estimated that the majority of spent solvents are captured under the Cat. 01.1 spent solvent entries. However, solvent regeneration can take place from LoW codes listed in the other categories too (see Chapter 22.2).

22.2 Treatment of spent solvents and other hazardous organic liquids

The main source of data for the treatment of spent solvents for this study is data from Eurostat (WStatR category 01.1). The nationally available data from the MS survey are used to complement this information but are only available for six MS (CZ, DK, EE, HR, LV, PT).[151] For Germany Destatis (2019) was evaluated: here, incineration could only be interpreted as one aggregate (D10 plus R1; as part of R1 co-processing is presented separately).[152] For spent solvent recycling (R2 treatment) only one aggregated figure without differentiation by LoW code is available (Destatis 2016).

A comparison of the data from the national contributions and Eurostat is included in Annex VI.

For France a contribution from Hazardous Waste Europe (HWE 2019) is taken into consideration. It is based on French ePRTR[153] data from the reporting of the hazardous waste treatment operators. The data were cleaned up and consolidated by HWE in order to ensure having all streams but only counting every stream once (no multi-counting due to transit/pre-treatment). As it did not follow the structure of the MS survey, the scope of the LoW codes taken into consideration varies allowing only limited comparison.[154]

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[150] Several MS did not report the volumes for "other chemical wastes (LoW 16)" due to lack of information concerning their composition. In general, no information was available with respect to the composition of these entries, in particular with respect to solid/liquid volumes or organic share.

[151] As an additional limitation, the split indicated for the different treatment options did not seem consistent in all cases (MS survey 2019).

[152] For an explanation of the waste treatment codes please refer to WFD (Annex III for disposal operations (D codes) and Annex IV for recovery operations (R codes))

[153] European Pollutant Release and Transfer Register, see https://prtr.eea.europa.eu/#/home, last access: 19/10/25

[154] A total of 156kt of waste partially going to R2 treatment were considered: 77% represented Category 01.1 LoW entries, 15% other entries (especially 080111* Waste paint) and 8% were aggregated as rest. As a consequence 120-140kt of spent solvents (Category 01.1) according to HWE (2019) are opposed to the total treatment of 370kt reported by Eurostat.

According to Eurostat 2019, the total treated volume of spent solvents (WStatR Category 01.1) is around 1.8 million t/a compared to a total generation of 2.4 million t/a.

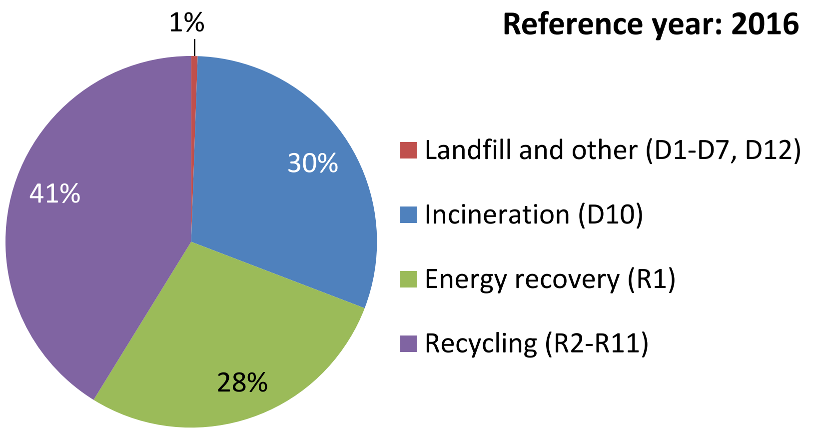
One explanation for this difference could be trade. It is found, however, that extra-European trade does not seem to play a major role and that in those cases where EU-28 trade is not balanced internally import generally exceeds export (see Chapter 22.3).

Another explanation may be qualitative and due to methodological aspects of statistical reporting. The data on generation, e.g. include secondary wastes[155]; for treatment only the final treatment for each waste shall be reported once (Eurostat WStatR metadata). If intermediate treatment is applied to spent solvent streams before final treatment it may decrease the volumes (e.g. drying or filtration prior to final treatment by another operator). According to HWE (2019) and ESRG (2019), multiple counting of streams may occur when wastes pass through a chain of operators (transit and pre-treatment operations), generally leading to an overestimation of waste streams.[156]

Thus, differences between generation and treatment cannot be reconciled on an aggregated level and the different possible reasons have to be kept in mind. The contribution of spent solvent trade is presented in Chapter 22.3.

The treatment options applied to spent solvents in Europe as reported by Eurostat are shown in Figure 22-3.

Figure 22-3 Split of treatment options for spent solvents in EU-28 (Category 01.1, Eurostat 2019)



On an EU-28 average, **recycling** reportedly accounts for the largest treatment option, with approx. 750kt/a reported to be recycled.[157] Based on information from ESRG this

[155] On a European average, 11% of the generated volume originate from NACE activity "Waste collection, treatment and disposal activities; materials recovery", see Figure 22-2.

[156] On the other hand, specifically for the case of spent solvents, ESRG (2019) estimates that in the case of some toll recovery operations not all used solvent is even classified as waste where it is argued that some operations do not represent the act of discarding.

[157] According to Eurostat WStatR metadata the category recycling aggregates all codes R2-R11 (cf. WFD Annex IV). With respect to spent solvent recycling R2 is the most relevant. Based on MS survey (2019)

volume seems to be very high: a survey conducted on behalf of ESRG among its members revealed a recycled solvent output of approx. 300kt in 2017 (ESRG-ETHOS 2018). Based on an estimated coverage of 80% ESRG members in the European recycling industry and an average yield of 75% (ESRG 2019), an input to recycling of only approx. 500kt would result.[158,159]

According to (ESRG-ETHOS 2018) the regenerated solvents produced by ESRG members include approx. 50% mixed solvents (≈150kt/a). Approx. 10kt/a, i.e. 3% of the total, are chlorinated solvents. The rest are different simple non-chlorinated solvents, but no information by substance is provided. Based on the fact that ESRG (2019) estimates a coverage of its membership of 80%, the total production of regenerates is estimated at 400kt/a.

More details on solvent recycling/regeneration are provided in the dedicated Chapter 24.

Landfill is hardly reported any longer. **Disposal by incineration** (D10) and energy recovery are reported in equal shares of close to 30%, corresponding to approx. 500kt/a each.

Energy recovery (R1) falls into the two cases of incineration with energy recovery and co-processing as support fuel in production processes (WFD Annex IV).

For the reference years 2016 and 2017 the European Cement Association provided a figure of approx. 700 kt/a of spent solvents being utilized in cement kilns (CEMBUREAU 2019, see also CEMBUREAU statement in Annex VII). Although no separate information concerning import from outside the EU was available, it was estimated that the amount is mainly generated within the EU (CEMBUREAU 2019). The value compares to an EU-28 total of close to 500kt reportedly treated as R1 in 2016 (Eurostat).[160] R1 treatment not only includes co-processing, but also incineration with energy recovery.[161]

One explanation may be that solvents processed to cement kilns as alternative fuel not only arise from Category 01.1 Spent solvents but also from other origins. However, as an example, Germany, as the generally largest generating and treating MS reports less than 10kt going to co-processing under LoW Chapter 08 (Destatis 2016).[162] The national statistics for Germany also indicate lower values for co-processing than reported by the cement industry: 80kt[163] and 130kt for reference year 2017, Destatis (2019) and VDZ (2018), respectively. For other organic wastes the

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some recycling may also be classified as R3 or rarely R9. The CZ contribution mentioned some R11 (for category 01.1, however, in negligible quantities).

[158] On industry side, data on volumes accepted by recyclers exist at company level (incl. LoW code, charge accepted, quantity, etc.); it is, however, currently not available on an aggregated level (ESRG 2019).

[159] It also has to be kept in mind that Eurostat reports recycling as aggregate R2-R11. Recycling activities other than recovery as solvent (R2) may be contained but based on MS survey (2019) were not found to be relevant.

[160] The reported amounts were at 600 kt and 444 kt for 2012 and 2014, respectively (Eurostat).

[161] E.g. DK and PT report R1 nearly exclusively as incineration with energy recovery (MS survey 2019).

[162] Destatis (2019), Table 4.1; no disaggregation by LoW code available, solvent content also needs to be taken into account.

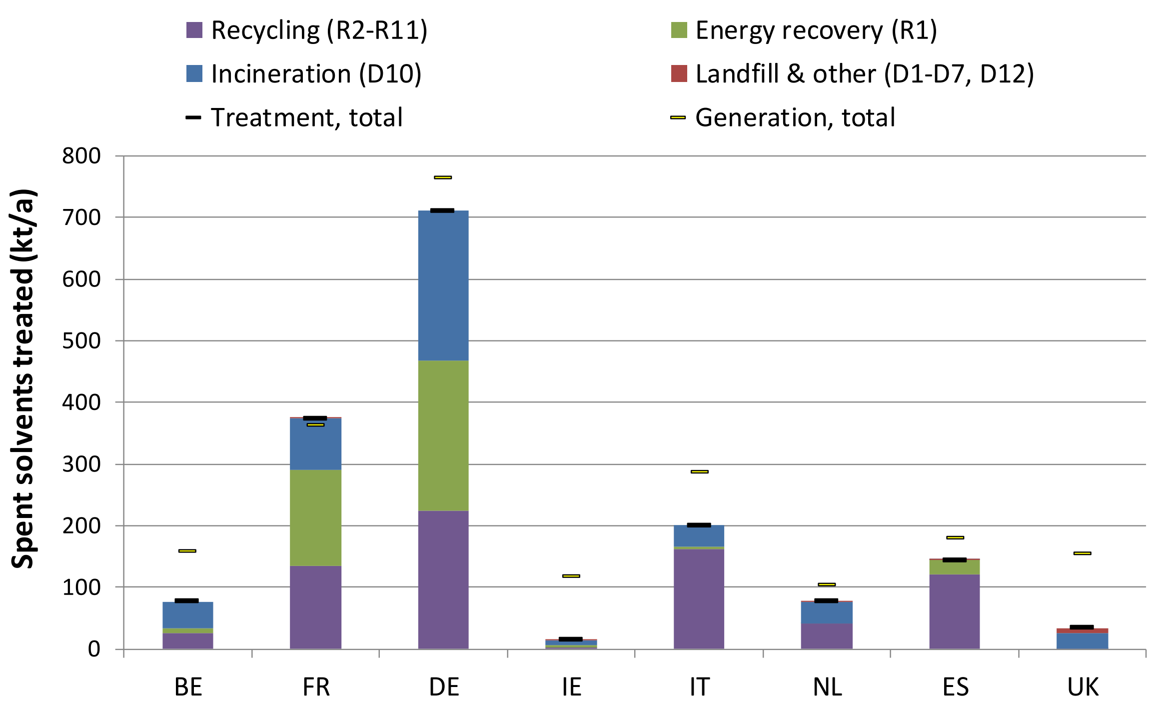
[163] Table 4.1, sum of the LoW codes included in WStatR Category 01.1, incl. considerable shares generated on-site; Note: the total volume reported by Destatis for each LoW Chapter in Table 4.1 is larger than the sum of the values reported by dedicated LoW codes in the respective chapter.

reverse is true: 120kt for "still bottoms and reaction residues" (LoW Chapter 07) reported by Destatis (2019) vs. approx. 60kt of other organic wastes (e.g. oil sludge, organic distillation residues) reported by VDZ (2018). This might point to differences in classification as another possible reason for deviations. In addition, for Germany also intra-EU trade may play a role.[164]

A third explanation is the assumption that in integrated waste management companies some streams which were initially labelled as R2 are actually sent to R1 operations following decisions at short notice based on economic considerations (ESRG 2019). This could simultaneously explain two aspects: the deviation found between official and industry values for co-processing and the higher values reported as recycling (R2) by Eurostat compared to the estimate for probable input quantities based on actually produced regenerated solvents (see above). This point should be analysed in detail in future work alongside a sound analysis of the question of imports and classification of waste streams.

Figure 22-4 and Figure 22-5 show the treated spent solvent quantities by treatment option for the different Member States. The reported generated quantities (cf. Chapter 22.1) are also included.

Figure 22-4 Spent solvents treated in the major generating Member States (Category 01.1, Eurostat 2019)



[164] The analysis carried out in this study did not reveal a large contribution of overall net trade for Germany (see Chapter 22.3). An evaluation of spent solvent trade by treatment option at final destination would additionally be required, however, to analyse whether import is predominantly linked to co-processing versus export to other options.

The highest volumes are treated in DE, with an equal split between recycling, energy recovery and disposal by incineration. The reported volumes are in reasonable agreement with the data from Destatis (2019) (see Annex VIII). As detailed above, some uncertainty exists with respect to spent solvent volumes used in cement kilns.

For France the volume treated according to Eurostat is considerably higher than the 120-140kt found by HWE (2019)[165]. The reported split of treatment options varies, with R2 being more pronounced according to Eurostat (36% and 26%, Eurostat and HWE (2019), respectively). According to HWE (2019), incineration without energy recovery (D10) is the dominating option (38%) whereas Eurostat reports 41% for R1 treatment.

Recycling dominates in IT and ES according to Eurostat. While no disaggregated information by LoW code could be made available from these MS, information from Spain on total solvent recycling capacity (close to 200kt/a, MS Survey 2019) seems consistent with the actual volume of 120kt reported as R2 treatment by Eurostat in 2016. According to ESRG (2019) it is more difficult to get permits for co-processing in cement kilns in IT and ES. As one explanation, societal opposition to (co-)incineration is reported (ESRG 2019, Tebert 2019).

Four MS (DE, FR, IT, ES) report close to 80 % of EU treatment. With > 80% the recycling rate reported for IT and ES is exceptionally high. The recycling rate in DE and FR lies around 33%. One reason appears to be the relative ease of accessing (co-)incineration options in these countries. In IT and ES getting permits for co-processing is reportedly more difficult (see also Chapter 25 Subsection v).

Among the other major spent-solvent generating MS the Netherlands and Belgium report some treatment. NL reports equal shares of disposal by incineration and recycling, while in BE disposal dominates. For IE and the UK the reported treatment activities are very limited. The UK nearly exclusively reports disposal by incineration (total waste treatment rose in 2016 from <1kt/a to 34kt/a predominantly due to an increase in incineration activity (D10)). Particularly for the UK this is striking because several companies are active in solvent recycling (and also blending in view of co-processing) there (ESRG 2019, see Chapter 24.3). For Ireland, the 2010 study on solvent recycling and treatment suggests a local on-site treatment of 50-60kt (partly also including on-site material recycling) while at the time off-site treatment was reported to occur predominantly abroad. At that time local cement plants, which could according to CTC (2010) easily absorb Irish spent solvent generation, applied for co-processing permits. Based on Eurostat data it seems, however, that to date no co-processing takes place in Ireland.[166]

Comparing spent solvent generation and treatment reported by Eurostat a particularly large difference becomes evident for BE, IE, IT and the UK. Analysis of trade indicates, however, that it can only partially be explained by exports based on the present analysis (see Chapter 22.3).

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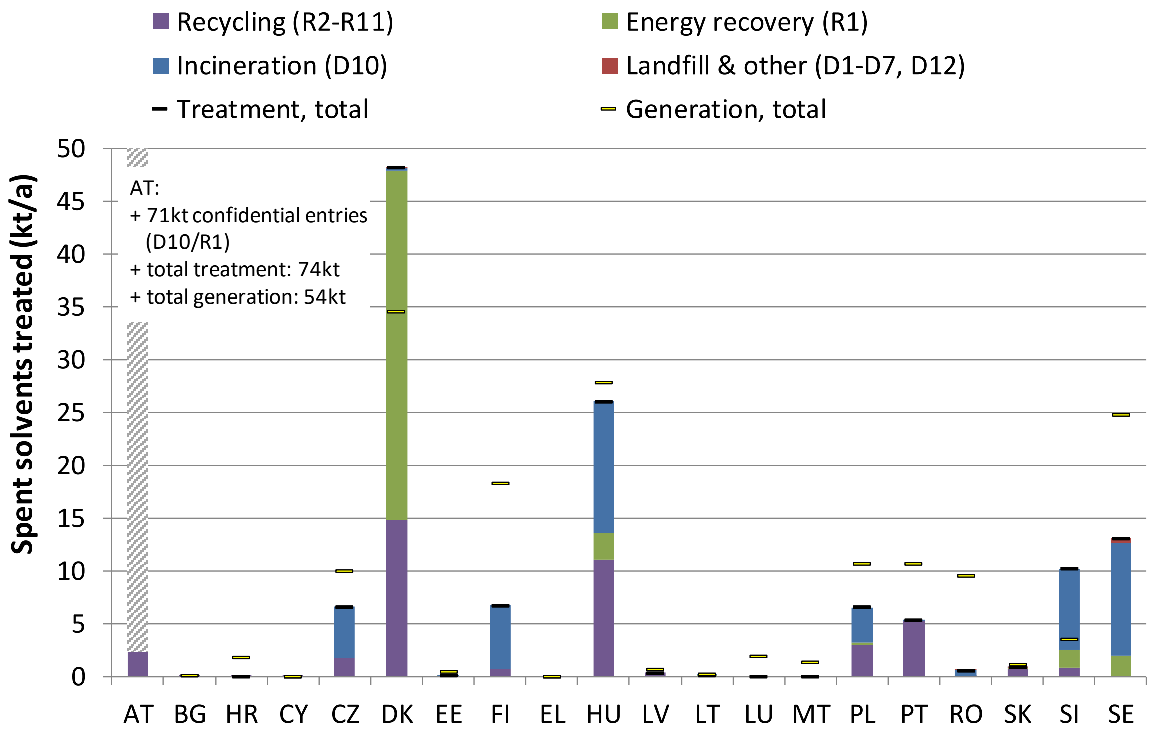
[165] It is estimated that there is a methodological reason for this large deviation.

[166] or very limited; total R1 reported at 5kt in 2016.

Figure 22-5 illustrates the situation of spent solvent treatment according to Eurostat for the remaining MS. With the exception of AT, DK and SI the reported treatment is below the generation in respective MS (for discussion on trade in spent solvents please refer to Chapter 22.3).

Figure 22-5 Spent solvents treated in the remaining Member States (Category 01.1, Eurostat 2019)



> Out of the 20 MS included in Figure 22-5 AT, DK, HU, SI and SE and, to a lesser extent, CZ, FI, PL and PT report relevant treatment. The average recycling share lies at 20%. This value may still be lower as it is based on a substantial contribution from DK where according to MS survey (2019) no solvent recycling takes place.*

* For one LoW entry (pharmaceutical origin) R3 treatment is reported but the volume is only 2kt opposed to 15kt recycling reported by Eurostat waste statistics (see Annex VI).

For DK the import of spent solvents to incineration is also relevant. With respect to its classification, the MS survey (2019) indicates that treated imported waste is most likely reported as R1 treatment, whereas treated domestic waste is often reported as D10 treatment even though it is the same type of waste treated in the same way.

The treatment is also reported to be higher than the generation of spent solvents for AT. The analysis of trade did not reveal a correspondingly high net import of spent solvents (see Chapter 22.3). No contribution to the MS survey was available for further insight. According to Eurostat less than 5% of the spent solvents are recycled. Whether incineration takes place with or without energy recovery (D10 or R1) remains undisclosed for confidentiality reasons.

Further information on the treatment of spent solvents in other MS obtained from the MS survey (2019) is included in Annex VI.

An overview of the treated volumes for all categories of waste streams analysed in this study[167] is attached in Annex VIII based on answers from CZ, DK, PT (MS survey 2019) and the partial evaluation of German national statistics (Destatis 2016).

For the other categories (except Cat. 01.1 spent solvents), a general tendency toward disposal by incineration (D10) is observed, followed by R1 treatment and other options (e.g. intermediate treatment). Recycling is only reported in minor quantities.[168] Particularly for spent antifreeze agents (160114*) HWE (2019) reports a recycling share of 81% (R3) for glycol recovery in France. For CZ 37% of spent antifreeze recycling (R2) are reported. For other hazardous liquids from LoW Chapter 07 (still bottoms and reaction residues) ESRG (2019) confirms that for solvent recyclers these do contribute less recoverable material. While beside their calorific value there may be some valuable metal content, a further recovery as a solvent is in general not a widely chosen option (ESRG 2019).

Solvents are also generally not recovered from sludges unless the small amount of solvent that can be separated has a high value and the separation is technically feasible (ESRG 2019).

The comparably large quantities of degreasing wastes generated in CZ (cf. Chapter 22.1) are reportedly not treated in the country (MS survey 2019). The present analysis of trade did not identify the corresponding export (see Chapter 22.3).[169]

As for waste generation, the publicly available statistics on treatment of spent solvents report an aggregate of defined LoW codes (WStatR Category 01.1). The differentiation by LoW codes is lost but several MS collect information by LoW codes.[170] LoW codes differentiate by origin (type of industrial activity generating the waste) and in very broad terms by physio-chemical properties (e.g. between halogenated and non-halogenated waste or between liquid residues and solids/sludges). However, with respect to identifying whether a spent solvent stream is suitable for regeneration, the LoW code is in general also not helpful because the specific chemical and hazardous nature of the waste stream usually dictates the waste treatment options (ESRG 2019). Usually the composition[171] of spent solvents reported under one LoW code varies widely so that no generalisation can be made. HWE (2019) also confirms that while a short list of LoW codes can characterize spent solvents going to regeneration, it is never possible to directly assign a treatment operation to a waste code.

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[167] Category 01.1 Spent solvents, other LoW categories containing organic solvents (see Annex V), other hazardous organic liquids from chemical processes (only LoW Chapter 07, see Annex V)

[168] DE has to be taken out of this general statement because for DE only categories D10+R1 were evaluated; for LoW codes 08 containing solvents considerable treatment other than D10+R1 likely takes place as generation is higher and there is no export (even some import) in this category (see Chapter 22.3). The same is shown for LoW codes containing solvents. Whether the streams go to recovery operations is not clear, but they are likely not recovered as R2 because the total recovery reported by Destatis as R2 roughly equals Eurostat data for recovery from spent solvents WStatR Cat. 01.1 (see Annex V).

[169] A possible explanation is that the degreasing waste is exported using only Y code and thus escaped the analysis in this study.

[170] For this study HR, CZ, DK, EE, LV and PT provided data by LoW code; in some cases the breakdown by treatment option seemed unreliable; Spain is currently implementing a National Registry for Waste Production and Management which will comprise information on waste treatment installations, the amount and type of waste they treat (disaggregated by LoW code) and the treatment option (disaggregated by WFD codes) for every waste treated from all regions in Spain (MS survey 2019); also German official statistics provide a breakdown by LoW codes (Destatis 2016).

[171] E.g. solvent content, level of impurities (water, solutes, particles), kinds of substances

The criteria used by solvent recyclers for deciding on the recyclability of a spent solvent stream are presented in Chapter 24. As a general rule, source segregation is an important prerequisite. Some further aspects are included in Chapter 24.

22.3 Trade in spent solvents and other hazardous organic liquids

The statistics on waste shipment (WShipR) were evaluated for data on the import and export of spent solvents and other hazardous organic liquids. Several entries are identifiable via their LoW code and included in the analysis according to the scope (cf. Annex V). For the entries lacking LoW codes those streams directly referring to spent solvents were identified and grouped with LoW codes from WStatR Category 01.1 Spent Solvents.[172] Several streams of other origins potentially refer to solvent-containing wastes but also include other wastes in their broad definition.[173] These were excluded from the evaluation if not additionally specified by a relevant LoW code. The latter potentially leads to an underestimation of traded volumes in the present evaluation.

The results of the WShipR analysis for spent solvents (WStatR Category 01.1) are shown in Figure 20-6 for the reference year 2016. The data for 2012-2016 are included in Annex IX.

Overall, the sum of all exports reported by the MS roughly equals the sum of all imports: 180kt and 165kt, exports and imports, respectively suggesting that extra-EU trade is limited. The observation is reasonable given that under the Basel convention trade with hazardous wastes is restricted to OECD countries (WShipR).

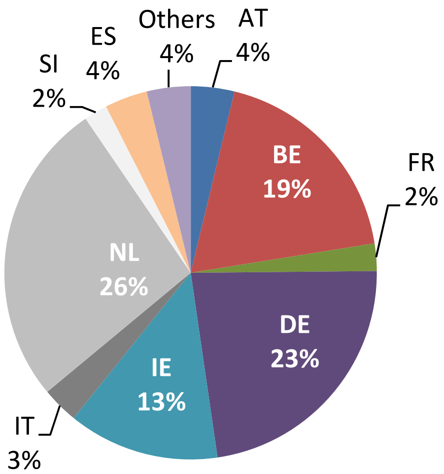
The identified traded volumes lie at approx. 10% of the volume treated inside Europe. At Member State level trade activity may be significant (e.g. for DK imports in the range of its national generation were identified). Moreover, the **analysis of the traded amounts by MS shows that the identified quantities in many cases fail to explain the difference between the national generation and the national treatment as reported by Eurostat** (Table 22-3).

[172] These include codes Y6 (Wastes from the production, formulation and use of organic solvents), Y41 (Halogenated organic solvents), Y42 (Organic solvents excl. halogenated solvents); also Y40 (Ethers) was included in the query but no entries were found where no LoW code was included.

[173] The respective codes include Y2 (Wastes from the production and preparation of pharmaceutical products), Y4 (Wastes from the production, formulation and use of biocides and phytopharmaceuticals), Y5 (Wastes from the manufacture, formulation and use of wood preserving chemicals), Y12 (Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish), Y13 (Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives).

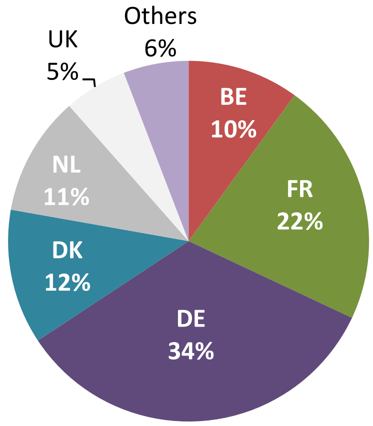
Figure 22-6 Export and import of spent solvents by MS and treatment (WShipR, WStatR Category 01.1, reference year: 2016)

Sum of all exports: 180kt

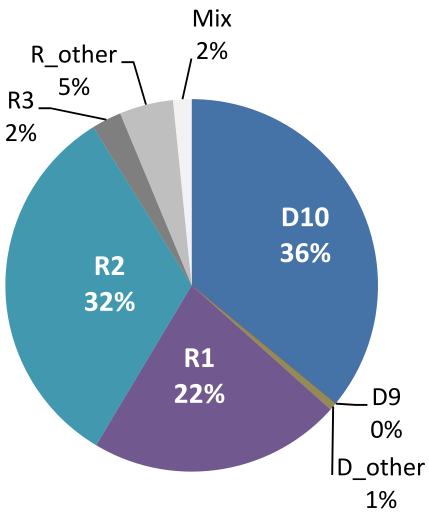


a) Export by MS

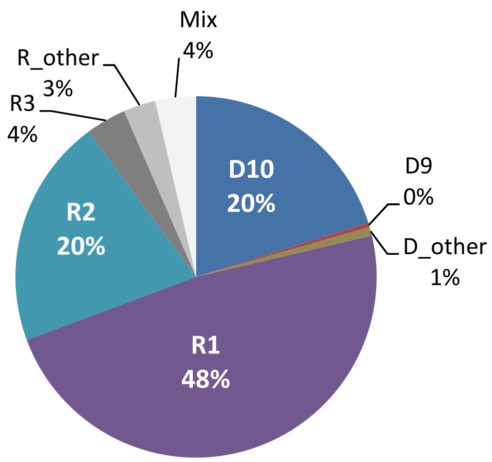
Sum of all imports: 165kt



b) Import by MS



c) Export by treatment



d) Import by treatment

Table 22-3 Generation and treatment of spent solvents compared to net trade from WshipR evaluation (WStatR Category 01.1, Reference year: 2016)

Unit: ktonnes	Generation	Treatment	Delta GEN_TRT	Net trade
	Eurostat env_wasgen	Eurostat env_wastrt	calculated	WShipR
AT	54	74	20	-5
BE	160	77	**-83**	-17
BG	0	0	0	0
HR	2	0	-2	-1
CY	0	0	0	0
CZ	10	7	-3	0
DK	35	48	14	20
EE	0.4	0	0	0
FI	18	7	-12	-1
FR	363	374	11	32
DE	766	711	-54	15
EL	0	0	0	0
HU	28	26	-2	0
IE	118	15	**-103**	-24
IT	288	201	**-87**	-6
LV	1	0	0	0
LT	0	0	0	0
LU	2	0	-2	-1
MT	1	0	-1	0
NL	105	78	-27	-30
PL	11	7	-4	2
PT	10	5	-4	0
RO	1	1	-1	0
SK	4	1	-3	0
SI	20	10	-10	-4
ES	180	144	-37	-3
SE	25	13	-12	-1
UK	156	34	**-122**	8
EU-28	**2350**	**1800**	**-500**	**-14**

With respect to the major generating countries large differences appear for BE, IE, IT and the UK.

The following reasons are identified:

- Trade: Incomplete tracing of spent solvent streams via the WShipR evaluation due to omission of entries under Y codes Y2, Y4, Y5, Y12[174] and Y13 where no LoW entry linking to solvent waste was available
- Waste generation: Inclusion of secondary waste volumes and/or contaminations (e.g. water content or other contamination) which may have been removed before submission to final treatment.[175]
- Waste treatment: Underestimation of reported treatment particularly in the case of the UK (no R2 treatment reported despite the fact that several companies are active in solvent recycling there (ESRG 2019), see Chapter 24.3).

In general, such differences can only be clarified in direct consultation with the Member States. From BE, IE, IT and the UK no contributions to this point were available from the MS survey (2019).

Based on the analysis of trade Germany is rather balanced with respect to spent solvents exports and imports, indicating that the gap between generation and treatment is predominantly due to reporting issues. This was assured by a cross-check with national data which suggests a total net trade in spent solvents of 14 kt in accordance with the TSW evaluation (see Table 22-4, UBA 2019). Values for other categories are also in good agreement. With respect to the overall transboundary shipment of hazardous wastes, UBA (2019) moreover confirms that for DE extra-EU trade is of minor importance.[176]

Table 22-4 German waste shipment notifications by type of waste (UBA 2019, Reference year 2016) compared to WShipR

UNIT: ktonnes	Import		Export		Net_trade	
	UBA	TSW	UBA	TSW	UBA	TSW
Halogenated spent solvents	15		12		3	
Non-halogenated spent solvents	40		29		11	
Waste paint, varnish, inks and adhesives	24	22	0	0	24	22
Wastes from chemical preparations	11		6		5	
Chemical reaction residues	52	37*	6	5	46	32
Total, spent solvents	**55**	**56**	**41**	**41**	**14**	**15**
Total, spent solvents & others	**142**	**119**	**53**	**49**	**89**	**70**

* The lower numbers from the WShipR evaluation might be explained by the fact that only selected chemical reaction residues (from LoW Chapter 07) were included, while UBA 2019 may also include other types of wastes (e.g. inorganic residues).

[174] only partially relevant for Category 01.1

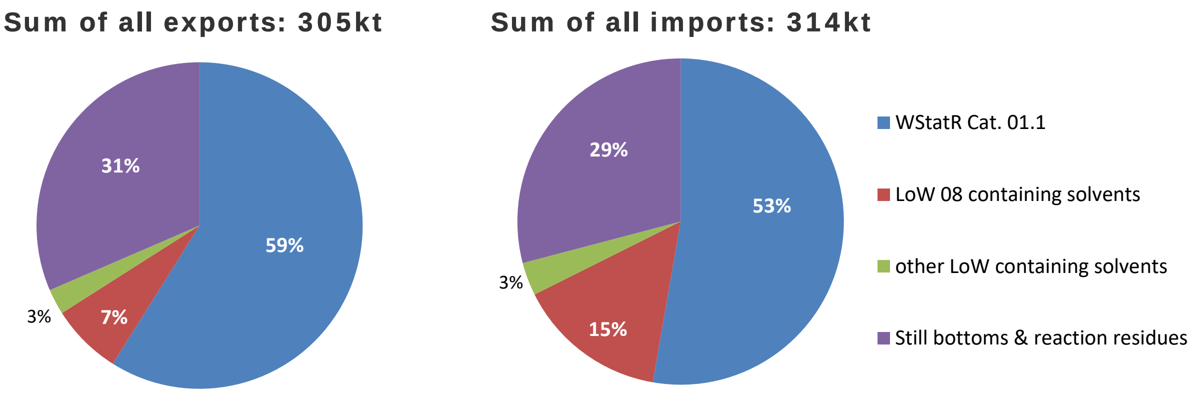
[175] See also Eurostat WStatR metadata.

[176] trade with EFTA countries roughly 10% of the streams traded with EU Member States, trade with other countries roughly 1% (UBA 2019); consistent with the fact that under the Basel convention trade with hazardous wastes is restricted to OECD countries (WShipR).

Also for ES and PT the overall quantities reported via the MS survey (2019) matched well with the volumes identified in this study. For DK the import reported by MS survey (2019) also agreed with the results of the present analysis. In addition, a relevant export stream was reported which would considerably reduce the net import (approx. 10kt instead of 20kt). Some further details of the information provided via the MS survey (2019) are included in Annex IX.

An illustration of the relevance of trade in spent solvents (WStatR Cat. 01.1) in comparison to the other waste streams containing spent solvents/hazardous liquids (cf. Table 22-1, Annex V) is shown in Figure 22-7. The overall traded volume is around 300kt/a for both exports and imports.

Figure 22-7 Trade in waste streams containing spent solvents and other hazardous organic liquids (WshipR, Reference year 2016)



a) Export **b) Import**

The picture is relatively stable over the last five years. Approx. 50 % of the trade activity is related to spent solvents (WStatR Category 01.1) and one third to "still bottoms and reaction residues". In the category "other LoW containing solvents" the largest part is due to the trade in brake fluids (between 68%-87% over the last five years) followed by antifreeze agents (8-27%). The identified trade in degreasing wastes is very limited (mainly from FR to DE/BE).[177] The suspected important export[178] of degreasing wastes from the Czech Republic could not be identified.

As in general it is found that the trade between the EU MS is rather balanced (no considerable extra-EU trade expected), it does not impact the material flow analysis of spent solvents on the EU-28 level. A balanced situation was also found for other hazardous liquid organic waste. For LoW 08 entries containing solvents and other LoW entries containing solvents EU-28 imports were found to be generally slightly higher than EU-28 exports (factor 2 and factor 1.3, respectively).

Due to the fact that LoW codes are not specified for all data on waste shipments in WShipR, it is possible that the present analysis underestimates the volumes.

[177] For LoW Chapters 03 and 04 only one single entry referring to solvent-containing waste was found.

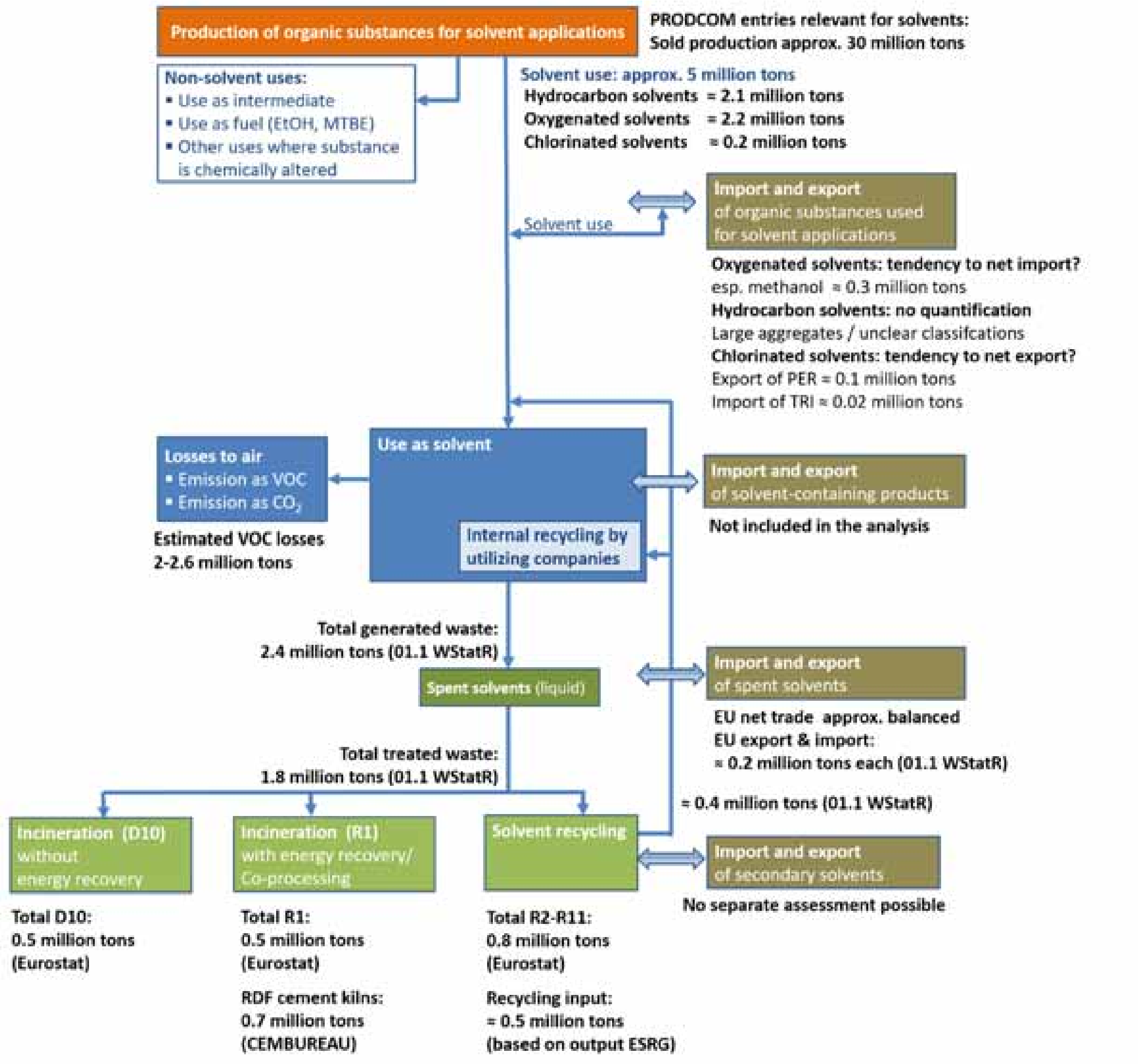
[178] Based on the analysis of generation and treatment, cf. Chapters 22.1 and 22.2

23 Overview over solvent flows in Europe

23.1 Summary of the material flow analysis

Figure 23-1 shows an overview of the identified solvent quantities produced, used and finally treated as waste in the European Union. The background of the data is discussed in the respective chapters (Chapters 20-22).

Figure 23-1 Solvent flows through the lifecycle for EU-28 (Reference years: 2017 / 2016 / 2015)[179]



[179] It is estimated that given the overall uncertainties of the data the difference in reference years is insignificant.

The overall **production of solvents** in Europe is approx. 5 million tonnes per year (JRC 2019 based on ESIG 2019). The total sold production (incl. use as intermediate or other, e.g. fuel) of the substances identified relevant for solvent use amounts to approx. 30 million tonnes per year (PRODCOM).[180] The solvent share for each substance is very variable – between (considerably) below 5% up to 100%. Generally, information on the solvent shares is not readily available for the various substances. In addition, PRODCOM only reports aggregate categories for some substances, making the application of a substance-specific solvent share impossible.

Based on expert judgment from industry representatives it was estimated that the produced solvent volume is composed of oxygenated and hydrocarbon solvents in approximately equal shares. Chlorinated solvents are estimated to be produced in volumes around 0.2 million tonnes per year or lower. The produced volume of nitrogen-containing solvents could not be quantified. ECHA tonnage bands for important representatives like DMF, NMP, acetonitrile, and TEA are in the range of 10-100kt each (local production and imports).

In Europe seven countries are mainly responsible to produce organic solvents (BE, DE, FR, UK, NL, ES, IT). These are also the countries where the highest sales of VOC solvents from EU-28 primary production are taking place (in total approx. 90% out of a total of close to 4 million tonnes reported by ESIG for EU-28 VOC solvent sales).

The analysis of the data on **trade** of solvent-relevant compounds (COMEXT integrated in PRODCOM) indicated a net import to the European Union for several oxygenated substances. The most outstanding example is methanol with a total net import of approx. 6 million tonnes, implying an import for solvent use of up to 300kt/a if the same solvent share used for production is applied. For several substances no estimate was possible due to their inclusion in aggregates in statistical entries. For hydrocarbon solvents the statistical entries are even more aggregated and classification less clear so that no quantitative trade estimates could be derived. For chlorinated substances a net export was found notably for the PER/TRI aggregate. Based on the fact that according to ECSA (2019b) TRI is no longer produced in the EU-28 in relevant quantities and rather imported when needed, a PER export of approx. 100kt/a and a TRI import of approx. 20kt/a were estimated for all uses. Trade in solvent-containing products may also be relevant but was not covered in this study due to the variety of products and the fact that information on their solvent content is not readily available.

With respect to **solvent use,** the repartition by application is reported to have remained constant over the last ten years, with over 50% of hydrocarbon and oxygenated solvents going to the coatings sector (mainly paints & coating, as well as printing and adhesives) (ESIG 2019). As generally only end uses are considered when the application of solvents is presented, uses in the primary manufacturing chemical industry are not included. Other relevant end uses include the pharmaceutical industry (9%) and industrial and professional cleaning applications (8%). For the consumer sector cosmetics, household applications/car care play a role (6% each).

Based on NMVOC emission inventories it is estimated that 2 to 2.6 million tonnes of solvents are released into the air per year (ESIG and EEA/EMEP inventories, respectively). The major contribution to these losses comes from the coatings sector, followed by domestic solvent use, the use of chemical products in industrial

[180] Out of approx. 100 million tonnes per year of organic substances produced in the European Union (PRODCOM codes 2014).

manufacturing and processing[181], printing and degreasing. It has to be stressed that from a circularity perspective emissions to air as NMVOC and as CO_2 represent losses. Thus uses with diffuse emissions but also uses where the solvents are captured in the off-gas and oxidised represent losses to the material cycle (as well as, of course, the direct use of solvents as fuel). The capture of solvents from off-gas is a particularly important issue in the field of industrial coating (and also some professional applications). However, material recovery of solvents from solvent-laden off-gases today seems rather limited.[182]

For the **waste stage** of solvents, public waste statistics offer data on spent solvents for all MS, but the included waste streams are limited to a defined aggregate (WStatR Category 01.1). This aggregate contains the relevant spent solvent streams from organic chemical processes (LoW Chapter 07) as well as waste organic solvents, refrigerants and propellants (LoW Chapter 14) and spent solvents collected from households (LoW Chapter 20). Waste streams containing solvents from other sources[183] are not included in this category but incorporated in other categories where they are aggregated with other wastes (e.g. solid, inorganic). Some aspects of these additional streams containing solvents were analysed in this study based on a survey among the EU Member States and are addressed below.

A total **generation of spent solvents** (WStatR Cat. 01.1) of 2.4 million tonnes per year is reported by Eurostat. This value includes impurities, but an average solvent content cannot reliably be indicated. In terms of quantities, a strong concentration of the waste on a few Member States can be observed. With approx. 700kt/a, by far the highest volumes are reported for DE (1/3 of EU-28 generation). The seven major producing Member States (BE, DE, FR, IT, NL, ES, UK) plus Ireland[184] report > 100kt/a each and together account for more than 90% of the EU-28 generation of spent solvents. 15 Member States[185] report a generation of around and below (some even far below) 10kt/a and together account for only ≈2% of European generation. AT, DK, FI, HU and SE lie in between and account for the remainder. The generation of spent solvent streams reported as "halogenated" is comparably high.[186] This might be explained by the fact that the actual halogenated solvents content of these entries is comparably low.

A total **treatment of spent solvents** of 1.8 million tonnes per year in the EU-28 is reported by Eurostat with an average recycling share of approx. 40%. The corresponding volume of 750kt/a of spent solvents going to recycling seems to be comparably high. Based on industry sources (ESRG 2019) a spent solvent input volume of approx. 500kt/a is estimated. A discrepancy was also found for the volumes going to energy recovery: While Eurostat reports approx. 500kt/a (incineration with energy recovery and co-processing), according to the cement industry association approx. 700kt/a of spent solvents are used as alternative fuel in cement kilns

181 According to the EEA/EMEP inventories; NFR Category 2.D.3.g Chemical products (EEA 2016/2019)

182 With the exception of toluene recovery in publication rotogravure printing which is common practice (JRC 2019).

183 In particular "Wastes from MFSU of coatings, adhesives, sealants and printing ink" (LoW Chapter 08) as well as degreasing wastes (LoW Chapter 11), brake fluids and antifreeze agents (LoW Chapter 16).

184 Due to important pharmaceutical industry, see, e.g. CTC (2010).

185 BG, HR, CY, CZ, EE, EL, LV, LT, LU, MT, PL, PT, RO, SK, SI

186 Based on Destatis (2019) for only DE alone approx. 200kt/a are reported whereas the total production of DCM, PER and TRI is < 400kt/a with an estimated solvent use < 200kt/a.

(CEMBUREAU 2019). Relevant imports from outside the EU are deemed unlikely by industry but need to be ascertained. Another possibility which may contribute to the discrepancy is the fact that according to ESRG (2019) in integrated waste management companies spent solvent streams originally foreseen for recycling (and reported accordingly) may actually be processed to co-incineration at short-notice based on economic considerations. This assumption needs to be further substantiated. It would simultaneously offer an explanation for why the volumes going to recycling according to Eurostat are found to be comparably high. Different classifications of streams concerning the term "spent solvents" may of course also contribute to the discrepancies.

Particularly high recycling shares are reported for IT and ES (>80%) where it is reportedly more difficult to access incineration options (see Chapter 25 v). For DE, FR and BE approx. 33% are reported to be recycled. The treatment reported for IE and the UK is very low. In IE no relevant external treatment of spent solvents seems to be taking place. In contrast, several recycling companies are active in the UK (ESRG 2019) even if this does not appear in the Eurostat figures. For the remaining 20 MS an average recycling share of only 20% is reported. This value may still be lower as it is based on a substantial contribution from DK where according to MS survey (2019) no solvent recycling takes place.

Beside external solvent recycling internal recycling is practised in a number of industries to recover solvents for reuse on-site. That way simultaneously net solvent input and waste output are decreased. From a global perspective it can hence be omitted for the material balance. As the volumes are potentially not covered by statistics[187] it was consequently excluded from the analysis of the present study.

For **spent solvents trade** the sum of all exports reported by the MS roughly equals the sum of all imports: 180kt and 165kt, respectively, suggesting that extra-EU trade is limited.[188] The identified traded volumes lie at approx. 10% of the spent solvent volume treated inside Europe. At Member State level trade activity may be significant. The analysis of the traded amounts by MS shows that the identified quantities in many cases do not at all explain the difference between the national generation and the national treatment as reported by Eurostat. It is suggested that the completeness of the analysis of trade in spent solvents could be increased by promoting the use of LoW codes to identify the shipments.

The volume of **regenerated solvents produced** is estimated to be close to 400kt/a. Among the member companies of the solvent recyclers' association[189], approx. 50% of the regenerates are recovered as mixed solvents while the rest are single substances. Chlorinated solvents are regenerated in volumes around 10kt/a. Regenerated solvents are reportedly traded to EU-28 MS and beyond depending on where the highest revenues can be achieved.

As indicated above, not all solvent-containing waste streams are included in the respective Eurostat waste statistics category (WStatR Cat. 01.1). Based on the

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[187] Eurostat (2013) stipulates the exclusion of on-site recycling from waste reporting. While experience suggests that in some cases these values may still be included there is no way of differentiating it from the data on external treatment.

[188] This is reasonable given that under the Basel convention trade with hazardous wastes is restricted to OECD countries (WShipR).

[189] Membership of solvent recycling companies in ESRG estimated at 80% by ESRG (2019).

reduced number of answers to the MS survey the waste volumes reported under other relevant LoW codes[190] were analysed.

With respect to solvent-containing waste streams from the coatings sector it generally showed that waste paint accounted for the highest volumes. In several cases quantities in the same range as for Cat. 01.1 were reported. However, it has to be kept in mind that the solvent content may be lower than for the dedicated spent solvent entries in Cat. 01.1. As no generalisable information with respect to average solvent contents was identified no further quantification was carried out. In general, the fact that coating applications represent the dominant solvent end use does not directly show in the generation of solvent waste streams due to the fact that a major share of the solvents is emitted to air during coating.

The volumes of spent brake fluids, antifreeze and degreasing agents are comparably small except for CZ where a relevant contribution[191] of degreasing wastes was identified.

Other hazardous organic liquids (still bottoms and reaction residues) may also constitute a relevant share but are reportedly less attractive to solvent recyclers.

23.2 Data availability and analysis of uncertainties

When compiling the material flow analysis for solvents several difficulties were encountered which should be kept in mind, e.g. when developing a reporting on solvents.

A) In general, the field of solvents is very broad due to numerous substances in question and various applications in which these can be used. Moreover, one solvent may be used in many applications and one application may use many solvents.

- Based on the currently available data on the production side (whether primary or regenerated) the solvents are known as substances, whereas in their use phase and waste stage they are aggregated with respect to different applications (where they are used / originate from).
- On the production side solvent use has to be differentiated from other uses, in particular use as an intermediate: solvent shares are not readily available.
- Deriving a reliable estimate on traded volumes seems a complex task for the variety of substances used as solvents and solvent-containing products.
- On the waste side no generalisation with respect to the solvent content of the solvent-containing waste streams is possible on the level of LoW codes.

B) Public Eurostat statistics (PRODCOM and waste reporting) have the important advantage that they offer information for all MS but there are some restrictions:

- PRODCOM sometimes only offers aggregates (not single substances) and the breakdown of production figures by MS is incomplete (one important reason being statistical confidentiality). PRODCOM does not consider the application of products therefore no information on the solvent share exists.
  For the Scandinavian countries the SPIN database includes substance

[190] See list of selected LoW codes for this study in Annex V.

[191] Nearly 20% of the CZ generation of all hazardous waste streams included in this study (see Chapter 22.1, Annex VIII).

information on quantities, industries in which it is used (NACE and national) and the function it is used for (USE Category) (SPIN 2019).

- Waste statistics for spent solvents only include a determined set of LoW codes in the publicly available aggregate "spent solvents" (WStatR Category 01.1).
  Several MS collect or start collecting information on waste streams by LoW codes. These data constitute a source of information for spent-solvent containing waste streams not included in Cat. 01.1 and also provide information on Cat. 01.1 on a more disaggregated level.
  However, even information by LoW code does not include a notion of the solvent content or the specific substances contained so that there is no direct link to an indication of the recyclable potential.
- Not all traded spent solvents are identified by their LoW codes in WShipR. For an improved tracing of shipments of spent solvents the specification of the LoW code (beside the compulsory Y code) increases transparency because it describes the shipments on a more disaggregated level.

C) For the material flow analysis in this study various sources were compiled as available. As a consequence the reference year for different lifecycle phases differs in some cases. Given the overall data uncertainties it is estimated, however, that these differences are not significant.

Possible additional data sources

The IED requires solvent-using companies which fall under the requirements of the IED to establish solvent management plans and solvent balances (IED Annex VII Part 7). Further research might evaluate to what extent these balances can be used to derive aggregated statistical information also taking into account the obtainable market-coverage given the thresholds of the IED (Annex VII Part 2). The solvent balances contain information on purchased solvent, internally recycled volumes, volumes emitted into the air (as CO_2 or VOC) as well as spent solvent generation.

For the treatment of spent solvents the ePRTR[192] might be another source. Completeness and accuracy of the available information in the different MS needs to be evaluated. Solvent recycling activities should generally be covered, considering the ePRTR thresholds.[193]

In view of solvent recovery from solvent-laden off-gas (see Chapters 24.2.2 and 25) it may be meaningful to differentiate spent solvents collected as liquids and spent solvents recovered from off-gas.

In addition, information on the amount of regenerated solvents produced is relevant. Currently this data exists on the industry side on company level but not on an aggregated level. Waste authorities generally do not have this data because, as regenerated products, they no longer fall under their remit (BE reply to MS survey 2019).

[192] European Pollutant Release and Transfer Register, see https://prtr.eea.europa.eu/#/home, last access: 19/10/25

[193] The ePRTR threshold for waste treatment activities lies at 10t/d and ESRG (2019) specifies the general capacities of solvent recycling plants at 3 to 100kt/a.

24 Collection and recycling of spent solvents

The WFD stipulates for all wastes, including spent solvents, that recycling is preferred over energy recovery or disposal according to the waste hierarchy. Similarly as with waste oils reasons why spent solvents are not suitable for regeneration are specific compositions or very low purity (JRC 2018). A fundamental difference with waste oils is that waste solvent qualities fluctuate much more than the quality of waste oil (JRC 2018). On the other hand, spent solvent generation is less dispersed than with waste oils (ESRG 2019).

According to ESRG (2019) the criteria for deciding on the recyclability of a spent solvent are:

1. Is the origin of the waste solvent known?
2. Is the composition of the waste solvent known and/or can it be analysed by the recycling company?
3. Can the waste solvent be recovered, e.g. distilled safely and according to the permit?
4. Is the recovery technically possible?
5. Can the waste solvent after recovery be reused by the client or sold at the market for safe reuse as a solvent and be consistent with product legislation?
6. Is the recovery economic?

In order to ascertain the feasibility of recovery a pre-assessment is carried out before a waste stream is accepted for recycling. It includes laboratory analysis and in some cases pilot or lab-scale test runs in order to assess key processing and safety parameters, expected product yield and necessities for appropriate treatment of arising wastes/waste water (JRC 2018). In general, it is required that the waste producer discloses the exact history of its waste in order to facilitate full analysis and choice of the most adequate treatment technology (ESRG 2019).

24.1 Collection of spent solvents

An important prerequisite with respect to solvent recycling is the separate collection of the organic liquid waste streams (Martens/Goldmann 2016). Also JRC (2018) states that regeneration takes place for ”clean waste solvents”. Generally, a lower degree of mixing decreases subsequent separation efforts and increases the probability to comply with the prerequisites for recyclability.

Based on the response to the MS survey[194] no EPR scheme or similar is in place for spent solvents or other hazardous liquids (MS survey 2019). No EPR schemes were identified for any of the other MS either. For Italy a deposit scheme for antifreeze agents purportedly exists (source missing). ESRG (2019) suggests that nothing similar for other solvents is in place in Italy. For the particular case of trichloroethylene, Smallwood (2002) mentions that in Sweden the distributors are required by law to supply a removal service with the waste being bulked together and removed by sea for recovery annually.[195]

For Germany a directive on halogenated solvents in general stipulates that chlorinated solvents after use have to be kept separated by the user according to the major constituent substance of the new (unused) product (HKWAbfV 2007). Distributors of

[194] Answers from BE (Flanders), HR, CZ, DK, EE, ES, LV, PT, SK

[195] No verification was carried out whether this provision is still in place.

chlorinated solvents are obliged to take back these unmixed spent solvents or guarantee a take-back solution by a third party. For Austria the directive on waste treatment obligations requires to keep halogenated and non-halogenated spent solvents and solvent-containing waste separated (AbfallBPV 2017). It does not, however, include a strict segregation by major constituent substance. It is estimated that a general economic incentive exists for keeping halogenated and non-halogenated solvent streams separate if disposal costs for halogenated spent solvents are higher. However, also segregation, in particular strict segregation by major constituents (if many different solvents are used), requires planning, storage space, and transport logistics.

In Portugal collection and transportation of waste is required to be made separately by type of waste using the LoW code to define the different waste streams to be collected and transported (MS survey 2019). However, according to this wording only a segregation by "type of waste" is required so that it might be possible to mix different solvent-containing wastes. Potentially, also same types of wastes with the same origin (LoW code) but from different companies might be mixed.

A general requirement for keeping streams separate emanates of course from the WFD which obliges MS to take the necessary measures to ensure that hazardous waste is not mixed[196], either with other categories of hazardous waste or with other waste, substances or materials. However, the wording of Article 18 describes a ban on mixing only for different "categories" of hazardous waste. Article 10 on recovery specifies that to facilitate or improve recycling waste shall not be mixed with other waste or other materials with different properties.

In general, no short-comings with respect to collection practices for spent solvents and other hazardous liquid waste were reported by the MS via the MS survey. Based on the Czech reply a focus on supervision for keeping waste streams separated is recommended (MS survey 2019).

The stakeholders involved in the collection process as identified via the MS survey are summarized in Annex X. In general, these include authorized collection companies and waste treatment facilities. For PT the waste producers themselves are also included.

According to ESRG (2019) the collection of spent solvent streams can be made either by solvent recyclers, by waste management companies and collectors or by waste brokers. However, there is a tendency that for recycling the collection is mostly done by the solvent recycling companies themselves, in particular for toll recycling. Waste brokers are in general excluded because intermediate trade is critical with respect to the exact knowledge of the history of the waste stream (ESRG 2019). Transport logistics (as a potential source of contamination/ alteration of the waste) must also be fully transparent. For this, recyclers either operate their own fleet or make a direct contract with logistics service providers to guarantee liability (ESRG 2019). Integrated waste management companies may be chosen for collection by solvent-using companies which require an inclusive waste management service for all of their produced waste. The waste management company will usually then pass the specific waste on to a specialised recycler but can also direct waste solvents to incineration options more easily (ESRG 2019). Thus, for recycling according to ESRG (2019) mainly the collector will be a solvent recycling company.

[196] Provided that it is not a waste treatment establishment carrying out mixing operations under the necessary permit.

An important point with respect to source-segregated collection of spent solvents is the requirement of storage capacity, either at the waste producer´s site or at the site of the regeneration plant (ESRG 2019). In that sense the availability of space can be a competitive asset of regeneration plants.

Except for the examples mentioned at the beginning of this section, no general national regulation was identified which directly obliges solvent users to keep their spent solvent streams separated by major constituents at the very source of waste generation. This observation fits with the information obtained from solvent recyclers that source segregation as a pre-requisite for recycling is purely based on sound business-to-business contacts (ESRG 2019). Source segregation of spent solvent streams is particularly important in view of high purity recycling and an issue which can be negotiated between the two parties – solvent user (spent solvent producer) and solvent recycler – with respect to logistics (e.g. who provides the storage space/transport fleet) (see Chapter 25).

24.2 Techniques for solvent recycling

In the case of spent solvents directly recovered from use as contaminated liquids, the recycling operation targets the separation of reusable solvents from the spent solvent mixture (Chapter 24.2.1). Options for the recovery of solvents from the gas phase are discussed further below (Chapter 24.2.2).

24.2.1 Liquid spent solvents recycling

The recovery can either target a regenerated mixture of solvent substances ("mixed solvents", in case several miscible solvents were already present in the waste) or single substances (if only one contaminated solvent is purified or a separation of mixed solvents is carried out in the recycling process).

Contamination of a solvent may result from mixture with air, water, particles, a solute, or with other solvents (JRC 2018, Martens/Goldmann 2016, Smallwood 2002). The techniques utilized for the recovery aim at removing the particular contamination and hence need to be individually adapted to the **nature of each spent solvent stream**[197]. The other determining factor is the **specification of the regenerated product**[198] which depends on the intended second use. JRC (2018) states that for certain reuses even simple techniques including filtration, centrifuging or stripping can be sufficient. A third factor are the **techniques available at the site,** as most recycling companies do not have a full range of all possible techniques (ESRG 2019).

The core process of most solvent recycling operations is a distillation to separate the liquid from impurities and potentially fractionate it into its constituents in order to recover marketable products meeting defined specifications. A description of different distillation techniques employed for solvent recovery can be found in ESRG (2017) and JRC (2018).

The distillation process may be more or less complex depending on the task to be achieved. Subcategories can be defined along processing principles: operating mode (continuous or batch), operating pressure, number of distillation stages (single or multi-stage), use of inert gases, and use of separation aids in azeotropic and extractive distillation (JRC 2018). Preceding or subsequent operations include mixing, solid-liquid separation (e.g. filtration, decantation), liquid-liquid phase separation,

[197] E.g. kind of solvent mix (azeotropes?) and/or kind of contamination (solids, salts, water…) (ESRG 2019)

[198] E.g. mono substance, mixture, water-free (ESRG 2019)

drying, or discoloration with activated carbon (ESRG 2017). Also separation by adsorption or pervaporation where one component selectively passes through a membrane and evaporates into the downstream phase may be an option (JRC 2018). Slater et al. (2011) and (2012) describe examples of using pervaporation and molecular sieve adsorption for IPA and THF recovery where these technologies can contribute in complex separation tasks (azeotropic or extractive distillation) to significantly reduce the expenditures (energy demand, waste generation) related to the conventional techniques.

The amount of residues from recycling, primarily distillation residues, is entirely dependent on the composition of the waste stream and can vary from zero to significant percentages (JRC 2018). In other words, depending on the composition, the yield[199] of the process can be close to 100% or considerably lower. If high value solvents are recycled (e.g. THF or acetonitrile), spent solvent streams with a content of only 30% may be accepted, but **in most cases a yield of 70% or higher is required for profitable operation** (ESRG 2019).[200] This also depends on whether the impurities are technically easy to separate or not. On average ESRG (2019) suggests a yield of 75%, meaning that 25% of the input remain as wastes.

In general, the benefits of solvent recycling, from a solvent user's economic point of view particularly when carried out onsite or as toll recycling, are the savings from reduced net solvent consumption and the reduced net amount of solvent hazardous waste generated. These oppose the expenditures for the segregation of waste streams and the recycling operation.

In coating applications liquid spent solvent streams particularly result from cleaning operations. The recovery and reuse of these solvents is discussed in the draft STS BREF (JRC 2019). According to JRC (2019) the recovery of cleaning agents (by filtration or distillation, on- or off-site) is commonly applied in most coating applications, especially in plants using large quantities of solvents. The recovery of purge solvents is applicable in all industries applying piping systems, e.g. paint or ink supply. It is commonly applied in the automotive industry where typically 80-90% of cleaning and purge solvents can be recovered for reuse (on- or off-site). In the case of off-site treatment, which may be more economically attractive due to larger quantities, the requirement of storage space at the user´s site is stressed for stocking used as well as returned clean solvents (JRC 2019).

According to JRC (2019) the recovery of cleaning/purge solvents is in general cost-effective. An exception may be the case that recovered solvents need further work-up to comply with the required specifications for reuse. Moreover, examples are mentioned where distillation is applied on-site to recover solvents from waste paints (e.g. in coil coating for cleaning purposes) or from waste ink (e.g. in publication rotogravure printing plants).

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[199] The yield is defined as mass-of-regenerated-solvent per mass-of-spent-solvent-incl.-impurities. It depends on the solvent content of the spent solvent as well as on the fraction of solvent which can be transferred into the regenerate. The latter is generally very high. According to ESRG (2019) in general 90% to 99% of the solvent in a waste stream can be regenerated where the distillation residues stay fluid. With slurry distillation residues this fraction will decrease typically to 70% – 85% (for example a thin film evaporator or batch column with agitator)

[200] Slater et al. (2011) report that for pharmaceutical waste the solvents content is typically 50-60% by mass with the remainder being water, reactants, and other compounds; for a particular case of NMP-recovery from an aqueous waste stream Pastore et al. (2016) report a NMP-content of only 17% where its recovery proved advantageous from a lifecycle economic and environmental perspective despite the high water content and corresponding energy requirements of the recycling process.

24.2.2 Recovery of solvents from the gas phase

In many applications solvents or solvent mixtures with high volatility are used in order to ensure their removal by evaporation during or after application. The main example is coating applications where the solvents separate from the paints, inks and adhesives during coating and drying processes. Solvents used for cleaning also evaporate to some extent.[201] After evaporation the solvents are present as vapour in the off-gas and thus more difficult to collect than in liquid phase. Based on a detailed analysis of solvent flows in spray painting[202] Harsch et al. (2014) state that out of the sprayed paint 100% of the solvent separates into the off-gas. Minor solvent quantities are lost in cleaning operations (removal of solvent-containing paint) and from solvent contained in paint residues.[203] Martens/Goldmann (2016) also confirm that during the painting process the majority of the solvent is released into the off-gas (95% in their case, while 5% go to the paint sludge).

Due to their harmful effects on workers and on the environment, in industrial and some professional applications solvent-laden off-gas has to be captured in order to reduce NMVOC emissions into the air (IED). Techniques for the recovery of solvents from solvent-laden off-gas are discussed in, e.g. Smallwood (2002) and included as BAT options applicable for coating industries using organic solvents in the draft STS BREF[204] (JRC 2019). They include condensation, adsorption and absorption (wet scrubbing).

According to JRC (2019) condensation is suited for high or medium solvent concentrations, and condensed solvents can typically be reused (or recycled). However, condensation is also used as a pre-treatment prior to oxidation[205]. A problem with respect to recycling may be the parallel condensation of water which may make energy-intensive drying necessary before reuse.

Adsorption of solvents can be realised on activated carbon beds or ceramic carriers impregnated with zeolites or carbon fibre paper. The off-gas flow is passed through the adsorbent and the solvent is retained on the surface. When switching to

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[201] For equipment cleaning in coating applications in particular when traditional cleaning solvents are used which are the same or similar to the solvents contained in the original coatings; this may be reduced by using less volatile substances or substitute cleaning techniques; in enclosed washing machines the solvents are captured and can be recovered and reused (JRC 2019).

[202] Example solvent-based paint: 50% solids, 50% solvent

[203] In the example analysed in Harsch et al. (2014) out of the originally acquired solvent-containing paint ≈10% are emitted in cleaning operations, ≈10% remain as paint residues and ≈80% are sprayed.

[204] Best Available Techniques (BAT) Reference Document on Surface Treatment Using Organic Solvents including Preservation of Wood and Wood Products with Chemicals

[205] Oxidation refers to the destruction of solvents in the off-gas by oxidation to CO_2 and water. In the draft STS BREF thermal oxidation is defined as "Oxidation of VOCs by heating off-gases with air or oxygen to above their auto-ignition point in a combustion chamber and maintaining a high temperature long enough to complete the combustion of VOCs to carbon dioxide and water" (JRC 2019). With simple thermal oxidation a significant amount of additional fuel is necessary to achieve and maintain the required temperature. With recuperative and regenerative thermal oxidation this amount is reduced by energy integration. For recuperative thermal oxidation additional fuel may still be necessary. For regenerative thermal oxidation the conditions become autothermal at VOC concentrations of 1.5-3 g/m³ (no additional fuel necessary, except for starting phases or standby) (JRC 2019). In that case excess heat may be generated and reused provided corresponding needs are available. With catalytic oxidation the required reaction temperature is reduced by use of a catalyst resulting in energy savings. However, additional fuel is still needed and the catalysts must be replaced/recharged periodically (JRC 2019). A further alternative is the utilization of solvent-laden off-gas as combustion air and supplementary fuel in combustion plants to generate electricity and heat (JRC 2019). Further details are given in JRC (2019).

desorption mode (or in the desorption region of the continuous rotor adsorber) the solvent is desorbed into a hot gas stream (nitrogen, air or steam) or by pressure swing. Due to a lower volumetric gas flow a higher concentration of the solvent in the desorbing stream is reached. This is often done on-site but may be done off-site when the waste gas flow is small (JRC 2019). In many cases adsorption is used as a means of concentrating-up VOCs prior to oxidation. Particularly for zeolite wheels JRC (2019) states that they are commonly applied as pre-treatment.

With respect to recovery the most prominent example is publication rotogravure printing where 95% of the toluene contained in the ink are recovered with activated carbon beds and desorption with steam (JRC 2019). Also for adhesive tape manufacturing desorption with steam is reported. In flexography and non-publication rotogravure printing it is less applicable because ethanol and ethyl acetate do not absorb as well to activated carbon as toluene (JRC 2019). Moreover, they are miscible with water so that desorption needs to be carried out with, e.g. hot nitrogen. After condensation a distillation process would be necessary to separate the solvent mixture. According to Tebert (2019) the solvents in off-gases from flexography and non-publication rotogravure printing are in practice oxidised and not recovered for economic reasons.[206] Also JRC (2019) states that in these cases the costs for adsorption and subsequent solvent recovery are higher than those of any thermal treatment. For packaging rotogravure printing, however, if ethyl acetate makes up over 90% of the total solvent used, JRC (2019) mentions the possibility that the reusable amount may be high enough that a plant becomes almost self-sufficient (no requirement for additional ethyl acetate purchase). The solvents contained in the off-gas in heatset off-set printing are generally also not recovered (Tebert 2019).[207]

Absorption is done using suitable fluids which are contacted with the solvent-laden air. An example for recovery for reuse is water-based scrubbing of DMF used in PU coating of textiles (JRC 2019). An absorption concept developed by a German company offers the possibility to either recover or oxidise the solvents after desorption (JRC 2019). Out of the German example plants (vehicle coating) using this technology only one of the plants really recovers the solvents for reuse (for cleaning with lower specifications) (Tebert 2019).

According to Tebert (2019) the recovery of solvents from captured off-gases in general represents a niche application with an economically driven tendency towards oxidation.[208] For the case of vehicle coating this view is also shared by BM Systems (2019). On the other hand, ESRG (2019) reports that solvent recyclers do receive spent solvents recovered from off-gases of coating applications but no information with respect to the related amounts was available. Also current waste statistics do not contain an indication (e.g. specific LoW code) which identifies spent solvents recovered from off-gases. A questionnaire issued to those European associations

[206] Saïca Flex recently announced that as of 2018 it recovers ethyl acetate as well as an alcohol mix of 86% ethanol, 12% propanol at its site in Luxembourg (Saïca Flex 2019); https://www.saica.com/en/saica-flex/, last acces: 19/11/04; the thermal oxidation unit was replaced by a distillation-based solvent recovery unit from DEC impianti which presents itself as world market leader in activated carbon solvent recovery systems, see https://www.decimpianti.com/index.html, last access: 19/11/04.

[207] There is a German company working on the recovery of the solvents from the ink. Gotha-Druck states that while oxidation is currently applied in the whole heatset web offset printing sector it is economically and ecologically inefficient; see http://www.gothadruck.de/umweltprojekt/, last access: 19/10/25

[208] Quality issues with respect to reuse may also play a role. These might be addressed by further processing/work-up and benefits need to be evaluated from a lifecycle perspective.

representing downstream users of solvents (ESVOC[209]) revealed that very little information (and in particular no data) could be made available at this level.[210] Following enquiry on the paint producers' side concerning the relative solvent volumes used directly in coatings vs. those used for cleaning purposes, BASF Coatings (2019) indicated that no data could be provided due to lack of information on the type and quantity of solvents used in cleaning applications at downstream users´ sites. While it should be possible to investigate these volumes from OEMs for single sites this would not provide a generalisable conclusion for the total market (BASF Coatings 2019).

As high volumes of solvents go into coating applications (up to nearly 50% of the solvent end uses, see Chapters 20.2 and 21) a large fraction of the solvents produced is lost to the material cycle by evaporation. However, the mandate for VOC emissions reductions in many cases makes the capture of off-gases necessary anyway and Smallwood (2002) states that there are clearly a number of ways of effectively removing the solvent which do not involve its destruction. Limiting are the facts that retrofitting is difficult[211] and that the quality of the solvent leaving the off-gas cleaning process may not be good enough for reuse making a further process necessary (Smallwood 2002).

Beside considerations regarding the use of less volatile solvents and completely alternative methods, the recovery of solvents from captured off-gases appears to be one starting point for reducing losses to the material cycle. Its environmental benefits should be ascertained from a lifecycle perspective which also needs to bear in mind that in the course of decarbonisation carbon will progressively become a scarce resource.

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[209] "European solvents downstream users coordination group" co-ordinated by ESIG

[210] Flexible Packaging Europe (FPE) confirmed that on-site recycling is done for the solvents used in cleaning processes and that recovery may take place from the solvents which evaporate during application of coatings (same or similar solvents as used for cleaning). No differences across Member States were identified. Waste inks, coatings and adhesives will generally be disposed of off-site. No purchase of externally recycled solvents is practised (FPE 2019). The European winding wires association stated that no liquid waste streams at all are linked to the fabrication of winding wires (EWW 2019).

[211] For the case of Saïca Flex (Luxembourg) the solvent recovery unit was retrofitted at the site where the oxidation unit was previously located (Saïca Flex 2019).

24.3 Solvent recycling industry

According to ESRG (2019), solvent recycling is essentially an industrial waste treatment activity of business to business associated with key manufacturing sectors including the chemical, pharmaceutical and surface coating industries. The recycling industry in Europe is hence traditionally concentrated in those MS with major corresponding industrial activities. These include DE, FR, BE, NL, IT, ES, and the UK (see also Chapter 20.2 and 21). An exception seems to be Ireland, where the pharmaceutical industry is strong but hardly any off-site recovery capacities are reported (CTC 2010).[212]

A map of solvent recyclers which are members of ESRG is shown in Figure 24-1. According to ESRG (2019) the association believes that its membership represents approx. 80% of the European solvent recyclers. For 2015 their combined treatment capacity was reported to be approx. 900kt/a in 41 major installations based on a survey among ESRG members (JRC 2018). ESRG (2019) estimates that this capacity may also include capacities for RDF generation. With respect to the relation between installed capacity and obtainable quantity of regenerated product it also has to be kept in mind that a single spent solvent stream may have to be passed through a batch operation several times in order to obtain the required purity. Therefore effective capacity of recycling plants may be considerably below the nominal installed capacity (ESRG 2019).

Figure 24-1 Solvent recycling companies in Europe (ESRG members)

Source: ESRG (2019); List of member companies is also available at: https://esrg.de/pages/members2.php?lang=DE, last access: 19/11/01

[212] Also for the UK Eurostat does not report any regeneration activity but this may be due to erroneous data. Several UK recyclers are, e.g. members of ESRG (ESRG 2019).

This map gives an indication of where major recycling activity is located but does not include all processing sites. E.g. in Spain 16 plants are reporting under R2 codes all confirmed active in solvent regeneration (MS survey 2019). They are spread across the whole country (with 50% of the installed capacity in Catalonia) and have a combined capacity of 200kt/a[213]. The Belgian reply to the MS survey indicates 16 plants operated by 15 companies in Flanders (MS survey 2019). The numbers of plants active in solvent recycling/regeneration as obtained from the MS survey are summarized in Table 24-1.

Table 24-1 Numbers of plants active in solvent recycling / R2 permit (MS survey 2019)

BE[214]	HR	CZ	DK	EE	LV	PT	SK	ES
16	3	n.i.	none	3	2	2 (R2)	6-7	16
(by 15 companies)		(R2 reported)		(small companies)		2 (R3)	(most <1kt/a)[215]	

According to the German statistics 48 plants report with R2 code there (Destatis 2016). In Germany there is the biggest European plant for PER recycling which also offers metal degreasing as a service and has capacities for recycling of other solvents.[216] According to ESRG (2019) for halogenated solvents there is only one other plant in Belgium.

According to ESRG (2019) the typical capacity of solvent recycling sites is between 3kt/a and 100kt/a. The majority of sites are businesses operated by small to medium sized specialist companies (ESRG 2019). Examples for multi-national integrated waste management companies also active in solvent recovery include Remondis, Suez, Tradebe or Veolia.

[213] Corresponding to an intake of 120kt in 2016 according to Eurostat and MS Survey (2019), see Chapter 22.2.

[214] Flanders

[215] One plant with a capacity of 3.5t/h (MS survey 2019)

[216] http://geiss-gmbh.de/, last access: 19/10/25

Substances targeted by recyclers

In general, from the point of view of recyclers, a solvent is any liquid chemical that after use can be purified by separation to a recognised level of sameness compared with a virgin substance or mixture and supported by analysis and conformance with existing regulation (ESRG 2019).

An overview of substances typically targeted by recycling is given in JRC (2018). It includes the main hydrocarbon, oxygenated and chlorinated solvents described in Chapter 19.2 as well as organic acids (acetic acid) and refrigerants:

– **Aliphatic hydrocarbons**	pentane, hexane, heptane, cyclohexane, isododecane, white spirit; but also kerosene
– **Aromatic hydrocarbons**	toluene, xylene, benzene
– **Esters**	different acetates; but also methyl formate
– **Ethers**	tetrahydrofuran, diiethyl- and diisopropyl-ethers
– **Glycols**	e.g. mono- and di-ethylene/propylene glycols
– **Ketones**	acetone, butanone, MIBK
– **Alcohols**	methanol, ethanol, propanol, IPA, butanols
– **Organic acids**	acetic acid
– **Chlorinated solvents**	beside the major solvents DCM, TRI and PER also chloroform and chlorobenzene
– **Refrigerants**	different chlorofluorocarbons
– **Nitrogen- or sulfur-containing solvents**	amides (e.g. DMF), amines (e.g. aniline, triethylamine), acetonitrile; DMSO
– **Solvent mixtures**	e.g. paint thinners, brake fluid, antifreeze, mix aromatic hydrocarbons (ESRG 2019)

With respect to benzene, ESRG (2019) states that while there may be recyclers which can carry out benzene recovery it is no longer a regular activity. Chlorinated solvents are also used less today in industry and there is a strong decline in the supply of this type of waste solvent (ESRG 2019). Some substances targeted by recyclers are not primarily produced in Europe but rather are imported (e.g. TRI, see Chapter 20).

According to ESRG (2019) the share of solvents recovered as mixtures is higher in Italy and Spain than in Middle and Northern Europe. As a reason the higher degree of organization in the field of thinners (mixed solvents) in these countries is indicated which includes the availability of corresponding outlets (ESRG 2019).[217] It is suggested, however, that there is no direct relation between the higher share recovered as mixed solvents and the fact that in IT and ES the overall recycling rates are exceptionally high[218] (ESRG 2019). The question of whether high-purity (single)

[217] In Southern Europe in vehicle coating generally solvent-based paints are used while in Middle and Northern Europe more water-based paints are employed (BM Systems 2019, ESRG 2019); a decreased market for thinners also resulted from the adoption of new paint systems (PU-based) which require water contents of <0.1% in the thinners. Drying to this level often requires too much effort.

[218] > 80% according to Eurostat env_wastrt, see Chapter 22.2.

solvents are recovered is rather a question of the extent of source segregation and the extent of treatment (related to investment requirements).

According to ESRG (2019) there is no general exclusion criterion for spent solvents accepted for recycling. Waste from the pharmaceutical sector can be accepted and also treated for external reuse if it can be guaranteed that no active ingredients (or any other relevant contaminant) are carried over to the regenerated product (ESRG 2019). According to ESRG (2019), the spent solvent-producing pharma companies put very severe controls on recyclers in order to secure that in no event any issues are caused which may be traced back to waste recycled from their sites. Often streams containing contaminants considered substances of very high concern (SVHC) are not accepted for recycling (ESRG 2019). However, some targeted solvents are classified as SVHC themselves. The French EoW criteria for regenerated chemicals define exclusion criteria with respect to acceptable input wastes for, e.g. PCB content and POP content (above a defined threshold) (FR EoW 2019, see also Chapter 24).

Modes of operation of recycling companies

Different modes of operation of solvent recycling companies are described in Smallwood (2002). These include

- recycling for sale on the market – open loop
- toll recycling – closed loop
- supply and take-back of solvents for temporary use
- blending for preparation of refuse-derived fuels

When solvents are recycled to the open market ownership changes to the solvent recycler and after regeneration the solvents are sold to another user. The use can be in a similar or a different application which, e.g. requires lower specifications.

With toll recycling the solvent is reused in a closed loop in the same process as the original solvent. The ownership remains with the solvent user (spent solvent producer) but the recycler carries out the regeneration.

An extended version, where moreover the ownership of the solvent lies with the recycler, is the leasing of solvents. It includes the supply and take-back of the solvents and just like toll recycling requires the ability of the solvent recycler to regenerate the solvents in a closed loop. A drawback of this option may be that it leads to interference with company decisions, as the recycler´s activity becomes part of the production of the client (ESRG 2019). The third mode according to Smallwood (2002) also implies that the solvent is only temporarily left to a client for use, but in contrast to the leasing option after take-back and recovery the solvent is taken into stock for potential use by someone else. This may be applied to solvents for cleaning or degreasing (Smallwood 2002).

Finally, if solvents are too contaminated for economic return to solvent use, an energetic recovery can be targeted by sorting and blending solvents for use as fuel (Smallwood 2002).

A solvent recycler can operate according to one or several of these modes but there are specific requirements for each (e.g. economic or with respect to logistics) which are discussed in Smallwood (2002). If a solvent recycler is also active in blending operations this carries the risk that spent solvents which can in effect be recycled are still passed to energy recovery if this option is economically more attractive (ESRG 2019).

In addition to these modes of operation ESRG (2019) mentions the option to process virgin solvents to higher purity if required by the user, e.g. in small quantities. Another service which can be offered by recyclers is general consultancy for solvent users to find the best solution for managing their solvent-based waste streams (ESRG 2010). In this context different options for the treatment of the used solvent can be evaluated (reuse, toll recovery, recycling or finally energy recovery) while the choice of solvent can also be scrutinized.

Developments – current and future

In terms of proximity, solvent recovery facilities tend to follow the main user industries so that in Europe they have been concentrated in those Member States with more solvent-using industry. According to ESRG (2019) that is slowly changing, as some large industries have moved production to other MS seeking the benefits of a cheaper labour supply and regional grants. In general recycling facilities were sited relatively close to large industrial activities because the cost of transport was a significant factor in the economics of recovery. Today it is less significant because specialisation becomes a more decisive factor (ESRG 2019).

According to ESRG (2019) historically the decision of a solvent user for the treatment of his spent solvent was purely based on economic considerations: low oil prices were linked to relatively low costs for fossil-based solvents resulting in a tendency towards disposal. According to ESRG (2019) this has changed for several reasons: higher energy costs, more complex solvent chemistries and the fact that environmental and waste disposal matters have to be taken into consideration. According to ESRG (2019) the influence of legislation (IED, WFD) has encouraged a better use of recovery techniques.

On the other hand, the demand for recycling services has decreased due to industry restructuring (e.g. exit of pharmaceutical companies from EU) and new technologies (e.g. water-based paints). This reduced the use of solvents and consequently the availability of spent solvents for recycling as well as outlets for regenerated (mixed) solvents (ESRG 2019).

As a consequence, according to ESRG (2019) there is in general an excess in capacity for the recovery of simple commodity chemicals with low specification concerning grade. Following this, in the last few years there was shift to a higher and a more specific quality of solvent recycling due to the demand on the market for increased toll recycling. According to ESRG (2019) solvent recycling companies were forced to invest in research, better technologies and state of the art installations to be able to achieve the required high quality of regenerates. This has enabled many operators to satisfy the quality demands from the specialised pharmaceutical and chemical industries who previously would have disposed of solvents by other means, often by incineration (ESRG 2019).

ESRG (2019) sees high purity solvent recycling and in particular the model of toll recycling as a growing activity. Thus, despite a decreasing use of solvents in the user industries the opportunities for the solvent recycling companies are expected to increase due to technology shifts (ESRG 2019). ESRG (2019) estimates that the advantages linked to toll recycling from the environmental, supply chain and economic point of view will increase the demand for this service in the next years. According to ESRG (2019), outsourcing to specialist companies has several benefits for users with respect to capacity utilisation, waste management techniques, sustainability and the handling of higher value more chemically complex organics (ESRG 2019).

A factor which is countering increased recycling has been a high demand from cement kilns and incineration facilities for solvents (as fuel) that makes the recycling of solvents and their mixtures comparably uneconomic (ESRG 2019).

The types of solvents to be recovered may also change. One reason may be the shift to less harmful solvents (see, e.g. Sheldon 2019 for a discussion with respect to organic syntheses). Another aspect which may lead to a change in the type of solvents used is a consideration of their recoverability after the process (Smallwood 2002). The properties which the solvent user needs for a product are not those which the recoverer needs for an effective separation process. Therefore, co-operation at an early stage is necessary in order to make a lifecycle-based decision with respect to the choice of solvent with minimum impact (Smallwood 2002, Seyler et al. 2006). Changes in technology (e.g. to less volatile solvents or to products with lower solvent content) may also impact the ways in which solvents can be recovered. Moreover, foreseeably the feedstock for solvent production needs to change from fossil to bio-based or CO_2-based alternatives which may also lead to the development of other substances (e.g. Sheldon 2019, RTB 2019).

25 Drivers for enhanced solvent recycling

Based on the analysis presented in the sections above, several elements were identified which are important towards promoting solvent recycling and which can be strengthened, or where changes can be introduced, in order to improve solvent recycling in quantitative and qualitative terms.

In general, the field of solvents is very broad due to the numerous substances involved and the various applications in which these can be used. Making general conclusions is hence difficult, particularly from a quantitative perspective. Consequently, this chapter discusses general qualitative aspects which can contribute to facilitate recycling.

The following aspects are addressed:

i. Role and relationship of users and recyclers
ii. Source segregation
iii. Choice and specifications of solvent
iv. Competition with primary solvent production
v. Competition with incineration of spent solvents
vi. Collection of solvents from off-gases
vii. End-of-waste

i) Role and relationship of users and recyclers

For several reasons the relationship between solvent users and recyclers is generally a very close business-to-business relationship (ESRG 2019). The reasons basically emanate from the criteria which solvent recyclers have to decide on the recyclability of a spent solvent stream (see Chapter 24). In general, the exact history of the waste has to be known in order to facilitate its full analysis. Transport logistics as a potential source of contamination/ alteration of the waste also need to be fully transparent. Finally, there needs to be a market for the regenerated solvent which preferably is the producing company itself.

In view of the development of recycling activities, ESRG (2019) estimates that potential for increased high-quality recycling (high purity grades) exists, in particular via toll-recycling arrangements. In order to tap it, both commitment by recyclers (offer capacity, set-up of plants) and by solvent-using companies (waste segregation at source, use of regenerated solvents) is needed.

On the side of the solvent-using company according to ESRG (2019) the required elements to start successfully a closed loop project for reuse of chemicals are the following:

1) *The project must have the full support by the management of the company. It needs recognition of the consequences in all departments of the user company:*
- direction: it's a strategic and long-term decision.
- production department creates the waste and has to reuse the recovered product
- quality department has to give their fiat to use the recovered product
- purchase department is involved because of cost setting and control.
- supply chain department: availability of the product (guaranteed by close loop system) logistics …
- environment department because it's waste that has to be recycled and has a positive influence on the waste balance, carbon footprint …
2) *Before starting the operational research it's necessary to know and agree the minimum specifications for the recycled product. Sometimes they are the same*

as virgin products, sometimes they are less severe but regularly they are stricter than the virgin because of the possibility of impurities even at a very low percentage.

3) *As every project is different good R&D work is necessary: starting with a theoretical study followed by simulations, lab tests and pilot runs.*
4) *It's not only the quality of the recycled product that's important but a successful project requires that the best available techniques are used.*
5) *Flexible and good logistics are necessary because the waste chemicals have to be isolated from other waste streams. Storage capacity is expensive and the faster the waste is recycled and returned for reuse then less new solvent has to be maintained in the solvent loop.*

(ESRG 2019)

As solvent recycling is in general not a core business for the solvent-using companies, ESRG (2019) estimates that particular benefits can be obtained from outsourcing this task to external recyclers. These include the guarantee of safety and quality standards, the choice of the most appropriate treatment technology and the ability to adequately respond to varying input compositions:

1) *Used solvents recovered for reuse have to be treated comparatively with virgin products.*
   If a waste solvent has to be recovered to a high standard product it has to be stored, transported and treated in very clean or dedicated installations. To guarantee the necessary quality full analyses are to be made before acceptance, during processing and before delivery of the recycled solvent.
2) *Every different waste stream needs extensive research to understand optimal processing techniques.*
   Because every stream can be different each used solvent has to be extensively evaluated to determine which is the most appropriate installation and the best production control parameters to ensure the necessary quality with the highest yield and using the least energy.
3) *Because the origin is a waste and a typical waste property is some variance in its composition, it is always important to understand the impact of changes even if small.*
   Most of the user companies are not used to working with raw materials that have varying compositions. It needs good and practical experience to produce output materials to the necessary standard of consistency and degree of required purity.

(ESRG 2019)

In addition, solvent recyclers may also offer other services like re-selling of make-up virgin solvent or offering storage space which may be a limiting factor at a solvent user´s site. Advice with respect to the most adequate solvent to be used, also in view of recyclability, is another benefit to be had from the close contact between user and recycler. A service solvent recyclers can provide to the chemical industry (which extensively recycles solvents itself) is smaller-sized separation equipment: this may be used to recover remaining valuable solvents from still bottoms with a volume too low to be treated in the original facilities.

From a recycler´s perspective, a sufficiently reliable supply with waste streams is a prerequisite for stable operation. If a solvent-using company changes its production or moves its site too far, the feedstock of the solvent recycler from this company is cut. For long-term stability it is hence crucial for a solvent recycling company to rely on solid and diverse partnerships with solvent users. Moreover, flexibility in production is important, in terms of volumes and quality of feedstock required (to be addressed, e.g. with storage space, flexible columns or other treatment equipment). This factor also facilitates the ability to respond to the needs of potential new clients. The minimum spent solvent volumes with which a solvent-using company becomes attractive for an external solvent recycler are generally case specific. They depend on economics (e.g. value of the solvent, logistics/transport) and the capabilities of the recycling plant.

From an environmental perspective the investments required by recyclers should also explore the possibilities of alternative separation technologies which may be less energy-demanding than conventional distillation (e.g. membrane separation processes).

ii) Source segregation

One of the important pre-requisites for solvent recycling, in particular for recovery of single solvents and toll recycling, is segregation of waste streams at the source. On the one hand this is self-evident because a lower degree of mixing requires less separation effort. It also becomes clear when looking at the requirements of recyclers (Chapter 24): the exact history of the waste has to be known, making an analysis of the composition possible, and a separation task needing to be technically feasible and economically viable. On the other hand, keeping streams separate can also be demanding in terms of logistics: separate storage tanks for the isolated spent solvent streams and potentially also for returned regenerated solvents have to be available which require space and separate transport. In this respect it may be a competitive asset of a recycling plant if it can offer storage space at its own site. In the case of toll recycling, moreover, all solvent in the loop has to be owned by the solvent user: the faster the regeneration of spent solvents can take place the lower this volume is (see above, point 5) ESRG (2019)). According to (Smallwood 2002) the latter may be a source of friction because a solvent recycler may prefer longer campaigns so that a clear agreement is required to that point.

With respect to legal provisions for source segregation, only one German directive was identified which requires that chlorinated solvents after use have to be kept separated by the user according to the major constituent substance of the new (unused) product (HKWAbfV 2007). This is limited to chlorinated solvents. Other provisions require segregation in more general terms, e.g. by type or category of waste. No general EPR scheme was identified for any of the MS.[219] The Czech reply to the MS survey recommended a focus on keeping streams separate, however, without any concrete suggestion.

It seems that cases where solvent users want to opt for toll recycling carry an inherent incentive for source segregation because the solvents need to be recycled to the same level where they can be re-introduced into the process. On the other hand, if strict segregation by major constituent substances (as e.g. prescribed by HKWAbfV (2007)) was made a legal requirement, the related effort would become automatic for any solvent user so that it would no longer be factored into economic considerations. A compromise may be the introduction of an economic incentive for source segregation. As an example, a fee is imposed for the collection of waste oils in Finland when they are not are kept separate at the source (see Chapter 15.3). It needs to be analysed, however, whether this approach can be transferred to spent solvents because the

[219] Smallwood (2002) quotes a Swedish provision for TRI according to which suppliers of TRI have to guarantee a take-back solution (limited to TRI). For Germany the said directive requires the guarantee of a take-back solution for the segregated streams of chlorinated solvents (HKWAbfV 2007).

generation pattern is different (generally less dispersed for solvents, ESRG 2019) so that collection practices incl. economic conditions probably differ.

iii) Choice and specifications of solvent

If a solvent is to be used in a process, its economic and ecological impacts should be evaluated from a life cycle perspective with the recyclability as one criterion in mind. Especially in the development of manufacturing processes it is important to also consider the end-of-life options already at an early stage of development where the possibilities to adapt configurations are still high (Smallwood 2002, Seyler et al. 2006). In cases where solvent users are not aware of the necessities which are important for the recovery it makes sense to seek exchange with specialist recyclers.

Another point which should be evaluated in close contact between user and recycler are the required specifications (Smallwood 2002). While of course complying with the necessary technical, safety and environmental requirements, a regeneration to unnecessarily tight specifications (e.g. in terms of permissible water content) should be avoided.

The types of solvents and solvent-containing products are likely to vary in the future, e.g. based on environmental and health considerations. Changes may result from a switch to other solvent substances (e.g. less volatile, less toxic, or sourced from renewable feedstock) or to products containing lower solvent contents (e.g. a continued shift towards water-based paints). The future dynamics should be considered when developing the solvent recycling industry.

iv) Competition with primary solvent production

Solvent recycling becomes attractive to solvent users when it is linked to an economic benefit compared to purchase of virgin solvent and waste solvent disposal costs. In this context ESRG (2019) states that in most cases the recovery cost is lower than the cost of purchasing new solvents. Also cost control is reported to be easier because a recovered solvent has a relatively more stable cost than primary solvents. Moreover, according to ESRG (2019) companies which use recovered solvents are less susceptible to supply shortages. With toll recycling arrangements the dependence on the external solvent supply market is decreased. ESRG (2019) estimates that the pressure on producing companies to secure constant feedstock and conditions is one of the drivers for future increased toll recycling.

Slater et al. (2012) report that the increasing costs for virgin solvent purchase and waste disposal also drive innovative approaches to recovery and reuse. Besides increasing raw material prices, the trend to more complex chemistries is a reason for comparatively higher prices of primary solvents.

In contrast, primary production in some cases may benefit from regional support schemes while none are currently in place for solvent regeneration hindering competitiveness (ESRG 2019). Also the fact that chemical and waste laws are still not fully matched creates barriers to the reuse of substances and mixtures.[220] According to ESRG (2019), chemical law recognizes the technical concept of sameness for a recovered chemical but waste authorities tend to use their own criteria. Better tracking of waste streams would also be desirable to improve the traceability of a stream´s fate from generation to final disposal/recovery (ESRG 2019). Finally, according to ESRG (2019) difficulties are encountered in some cases with subjective

[220] One aspect in this respect also is that compartmental legislation favours big industry because specific regulatory cost decreases with size (ESRG 2019).

end-of-waste interpretations of MS authorities in particular for recovered mixtures (see also point vii). ESRG (2019) also indicates that with regard to user´s acceptance of regenerated solvents a drawback results from the fact that recovered materials generally do not bear REACH registration numbers. According to ESRG (2019), this can create a barrier to their recognised status as materials suitable for reuse. As regenerated substances/mixtures often have an originally primary produced equivalent, they can be exempted from re-registration because the substance is already registered under REACH. The solvent recyclers are, however, not allowed to use the specific registration number of a primary manufacturer in their Safety Data Sheets. For a user this can result in difficulties, e.g. in cases where there is an electronic requirement to introduce a REACH registration number when accepting a substance. According to ESRG (2019) the development of a methodology to better identify recycled materials is desirable.

v) Competition with incineration of spent solvents

On the one hand, there are spent solvent streams which cannot be accepted for recycling due to unknown origin or a specific contamination. However, economic competition also exists between the two treatment options of incineration and recycling for spent solvents which are potentially fit for recycling. Following the waste hierarchy, there is a clear requirement to prefer recycling over incineration unless it is proven for a specific case that, from a life cycle perspective, incineration is preferable with respect to environmental performance (WFD).

According to ESRG (2019), there are no provisions in place which impede the fair market competition between the two treatment options for spent solvents. However, incineration is often more economically attractive even in cases where recycling can be carried out (ESRG 2019). The implementation of the waste hierarchy is hence required to assure that spent solvent streams acceptable for recycling are channeled into this direction.

It seems that the implementation of the waste hierarchy is not uniform across Member States. One indication is that the share of spent solvents going to recycling in Italy or Spain is considerably higher than in other MS. According to ESRG (2019) there is no particular legislation in place, the frame is EU-based (WFD). Societal opposition to co-incineration is suggested as one reason for why the incineration option is more difficult to access in IT and ES (ESRG 2019, Tebert 2019).[221] In contrast, for Germany a ministerial act exists intended to support competent authorities charged with implementing the waste hierarchy: It globally assumes equivalence of the two treatment options for hazardous wastes from wide range LoW codes (BMU 2017). These LoW codes include nearly all codes relevant for WStatR Category 01.1 "Spent solvents"[222] as well as many LoW codes from WStatR Chapter 08 "containing solvents"[223] (cf. Annex V). The justification is that streams originating under these codes are generally too contaminated to guarantee the required proper and safe handling in recycling processes. As a consequence, the act suggests that for the specific streams energy recovery is automatically equivalent to recycling, leaving the full choice to the waste producer/holder. In case that the competent authority wants to enforce the principle preference of recycling it has to carry the full burden of proof

[221] It was not clarified whether this opposition is rather supposed to be located in the population itself or with the competent authorities.

[222] except for 070603*, 140101*, 200113*

[223] except for 080121*, 080312*, 080411*, 200127*

for this exceptional case. Given that recycling plants throughout Europe lawfully treat spent solvents with the LoW codes in question it seems highly questionable whether this general reversal of the waste hierarchy is appropriate.

No other specific pieces of legislation were identified, but it is suggested that an enquiry on how the different MS manage the implementation of the waste hierarchy with respect to spent solvents would be profitable to shed light on the different approaches. ESRG (2019) also identifies the implementation of the waste hierarchy as an important weakness with respect to the competition between solvent recyclers and incinerators.

vi) Collection of solvents from off-gases

The material flow analysis revealed that solvents are largely lost to the material cycle via emissions into the air (Chapter 21). On the one hand, this can be addressed by using fewer volatile solvents or changing to solvent-free applications. This aspect is particularly important for dissipative uses, where emissions into the air cannot be captured. On the other hand, based on performance considerations applications may continue to rely on the use of solvents and their volatilisation during the process. Today, under the IED, the capture of solvent-laden off-gas is required for industrial and some professional applications where solvent emissions are comparably concentrated.

Techniques for the recovery of solvents from off-gases are included as BAT options in the recent draft STS BREF (JRC 2019, see also overview in Chapter 24.2.2). However, these can also be used for achieving higher VOC concentrations in the off-gas prior to abatement by oxidation. No preference for either option – recovery for reuse or oxidation – is included (JRC 2019). The extent to which solvent recycling from off-gases is actually practised at the moment is unclear,[224] but several sources indicate that it is limited. A major reason are economic considerations (JRC 2019, Tebert 2019), but quality aspects[225] may also play a role. In general, VOC treatment in off-gases today appears to focus more on avoiding the environmental harm of VOC emissions to the environment and less on closing the material loop.

Still, beside the widely practised toluene recovery from publication rotogravure printing, cases also exist for other coating sectors where solvents captured in the off-gas are recovered. Three specific examples are illustrated in the following.

The German company Gotha-Druck is currently active in the field of solvent-recovery from heatset offset printing. Based on the available documentation it appears that they are currently in the development phase and that their development is rather unique for the sector.[226]

The solvents in the inks of a packaging rotogravure printing plant in Luxembourg (Saïca Flex) are being successfully recovered (Saïca Flex 2019). The installation was supplied by DEC Impianti, an Italian manufacturer of activated carbon adsorption technology (Saïca Flex 2019). According to Saïca Flex (2019) three thermal oxidizers (in place since 2003) were replaced by the solvent recovery installation. Experience with a similar site in Italy reportedly exists. According to the supplier itself, DEC

[224] With the exception of toluene recovery from publication rotogravure printing, where 95% are reported to be recovered for reuse (JRC 2019).

[225] E.g. recovered solvents from off-gases may require a further, potentially energy-intensive, work-up before reuse.

[226] http://www.gothadruck.de/umweltprojekt/, last access: 19/10/25

Impianti has a long-standing history in solvent recovery system based on activated carbon adsorption with different technological settings (DEC Impianti 2019).

At Saïca Flex ethyl acetate (purity > 99.5%) and an alcohol mixture (86% ethanol, 12% IPA) are recovered. The recovery of these solvents is reported to be sufficient to cover the additional solvent needs of the company so that the only net solvent input to the company are those solvents originally contained in purchased products (e.g. inks). The recovered products are either directly reused on site, sold to ink makers or stocked (Saïca Flex 2019). According to DEC Impianti (2019) other solvents like isopropyl acetate, hexane or MEK, and of course toluene, are also recoverable.

The German company AWS Group developed a wet-scrubbing process which was installed in three German vehicle coating installations (Tebert 2016). One of these recovers solvents for reuse, albeit in cleaning applications with lower specifications (Tebert 2019). According to Tebert (2019) the company has, however, since gone bankrupt.

Given the relatively high fraction of solvents which is lost to the material cycle through emissions into the air[227] it appears that recovery from solvent-laden off-gas could significantly contribute to enhance the circular economy. Future work should elaborate on the options and specific barriers for each relevant sector and evaluate the environmental and economic impacts from a life cycle perspective. Where it is technically feasible and beneficial from a life cycle-based environmental perspective it should be supported. In particular, with a view to decarbonisation, a life cycle analysis should also take into consideration that carbon will likely become an increasingly valuable resource.[228]

vii) End-of-waste

The clear recognition that a waste which has undergone a recovery operation is no longer a waste but can be safely used in a process as a secondary raw material or product is an important prerequisite for closing the material cycle. The principle provisions are set out in the WFD, Article (6).

From the side of the solvent recycling industry (ESRG), a Code of Practice has been developed by which association members confirm that a regenerated solvent requires no further treatment before use by the end user (ESRG 2017). According to ESRG the chemical parameters targeted with solvent recovery are essentially those of **sameness** compared with a virgin substance or mixture so that the first three conditions set out in Article 6(1) of the WFD are generally easily demonstrated (ESRG 2019, ESRG 2017). With respect to the fourth criterion, more proof is necessary to ensure that the use "will not lead to overall adverse environmental or human health impacts" which might be caused by contaminants not present in the original substance/mixture (ESRG 2017). In order to address this aspect appropriate testing, full chemical analysis and REACH compliance are assured. As a consequence, a solvent regenerated under the ESRG Code of Practice is always fully analysed and sold with a REACH/CLP compliant safety data sheet as well as usually entitled to REACH registration exemptions (ESRG 2019). According to ESRG (2019) regenerated solvents

[227] as NMVOC or CO_2

[228] Due to the limited availability of carbon from sustainable biomass the use of CO_2, from (biogenous) point sources, but also directly captured from the air, is being discussed as future alternative feedstock for a low-carbon economy then requiring energy-intensive reduction. On the other hand, if large-scale electrolysers are deployed to produce (renewable) hydrogen (for direct use or CO_2 reduction), also pure oxygen production (from electrolysis) will increase which may reduce the availability of nitrogen from air separation.

which are exported outside the EU also generally comply with REACH requirements. This is supported by the fact that the regenerated solvents are often sold to traders inside the EU before being exported (ESRG 2019).

The certificate issued under the ESRG Code of Practice is mainly intended to assure the users of regenerated products of their quality. It can also be used as an additional argument to justify end-of-waste status to authorities.

Currently, only France has introduced EoW criteria for regenerated chemicals and chemicals prepared for reuse which also include solvents (FR EoW 2019 and 2018, respectively).[229] For regeneration some exclusion criteria are defined with respect to acceptable input wastes. These include, e.g. PCB content[230] as well as POP content (above a defined threshold)[231]. Moreover, the order specifies that the recovered chemicals "shall have technical characteristics that enable their use for the same purposes and with the same level of safety as the chemical or object that produced the waste from which they were obtained" (FR EoW 2019). Depending on the interpretation, the latter might imply that the recovery of lower specification cleaning solvents from solvents which were originally used in an application with higher specifications does to not satisfy the EoW criterion.

In other MS, decisions on EoW status are taken on a case-by-case basis. According to the MS survey (2019), solvent regeneration is carried out in Portugal in industrial facilities (manufacturing industry) with the production of a product. For Denmark, no EoW criterion is defined given the complete lack of regenerating industry (MS survey 2019). The Czech reply states that the exact end-of-waste conditions are established in the permit and operating conditions of the facility and approved by the regional authority (MS survey 2019). In Flanders the holder can perform a self-assessment or submit an application for a case-by-case decision by the OVAM. A guidance document is available stipulating rules for defining end-of-waste status (MS survey 2019). The OVAM guidance as well as a systematic overview of the different approaches in the MS is presented in MiW/IMPEL (2019). The practical tool developed by MiW/IMPEL (2019) is intended to help regulators and operators assess whether materials meet the conditions and requirements for end-of-waste by providing information on procedures across Europe. It also contains a proposal for a voluntary database to record the outcome of the case-by-case assessments. By enabling exchange of information, the latter could contribute to encourage uniformity across Member States and allow for the identification of common technical and environmental standards, while public access would contribute to increased transparency and building trust in secondary products (MiW/IMPEL 2019).

The analysis of regenerated solvents to determine their quality is, in general, comparably easy due to their homogeneous liquid nature.[232] Consequently, according to ESRG (2019) the case-by-case approval of the EoW status of a regenerated solvent is generally not a problem: potential disagreements can usually be settled in negotiation between the recycler and the competent authority. However, in somes

[229] Austria has introduced EoW criteria for alternative fuels used in co-processing which also include spent solvents; https://ec.europa.eu/growth/tools-databases/tris/en/search/?trisaction=search.detail&year=2009&num=633, last access: 19/11/10.

[230] in the sense of Article R. 543-17 of the (French) Environmental Code (FR EoW 2019).

[231] limits set out in former Regulation (EC) No 850/2004 (now Regulation (EU) 2019/1021) (FR EoW 2019).

[232] Provided that the origin and specific composition of the spent solvents are known which is among the requirements of solvent recyclers for accepting streams for recycling (see Chapter 24).

cases deviating EoW interpretations between and within MS still constitute a hindering factor especially for recovered mixtures (ESRG 2019).

The important aspect of end-of-waste declaration is the clear definition that a waste which has undergone a recovery operation is no longer a waste but can be safely reused. It gives confidence to users and provides planning reliability to recyclers. Which way to address this aspect is most effective for the case of solvents should be closely followed up. In this context also the "Study to assess Member States' practices on by-product and end-of-waste" commissioned by the European Commission (DG ENV) in December 2018 is expected to provide valuable input.

26 Outlook

One aim of the present study was to provide a detailed picture of the flows of spent solvents in the European Union and to analyse the possibilities of their recycling. In order to increase the spent solvent feedstock available for recycling and to facilitate the recycling of solvents the following important points were derived:

A major reason for varying shares of spent solvents to recycling in the MS seems to be different approaches to the **implementation of the waste hierarchy**. A systematic enquiry into the ways the MS implement and enforce the waste hierarchy for spent solvents is required. The justifications for deviations should be made transparent and their admissibility should be assessed. If applicable, the MS should also provide information on supportive mechanisms for the priorisation according to the waste hierarchy.

The export of spent solvents to incineration facilities in other MS should only be allowed in cases where the deviation from the waste hierarchy is adequately justified. Experience with waste oils suggests that recycling rates are higher for MS which control waste oil export by intervention options in favour of regeneration (see Chapter 17).

For tracing the shipment of spent solvents the reliable use of LoW codes (in addition to the Y codes) is desirable to increase transparency.

Source segregation is one important prerequisite to facilitate recycling. For solvent users it is generally linked to more demanding logistics. It can be negotiated between solvent users and recyclers but also the political/regulatory/legal environment should be supportive. Beside strict provisions this may include economic incentives for keeping streams separated. Drawing on the positive experience with other waste streams, EPR schemes with different accounting for segregated and non-segregated spent solvents might be taken into consideration. A careful design would be required in order not to disturb the existing functioning settings based on direct contact between solvent users and recyclers. Follow-up work is necessary to evaluate the possibilities.

In order to increase the available feedstock for recycling, the **feasibility of channeling solvents in off-gases to material recovery** should be analysed. Techniques for solvent recovery from captured off-gases are included as BAT options for the coating industries using organic solvents in the draft STS BREF[233] (JRC 2019). However, the BAT does not establish a preference for recycling over VOC abatement by oxidation. Some examples where solvent material recovery from off-gases is feasible or being developed were presented in this study. A broader evaluation should include the technical options[234] for all relevant applications and elaborate on the economic impacts and environmental benefits from a life cycle perspective. If feasibility is generally proven, the waste hierarchy might prospectively be applied to captured solvent-laden off-gases too. This would imply following the priority order specified in Article 4 (1) WFD and in particular prioritizing solvent material recovery over oxidation. Departing from this order in specific cases would then need to be justified by life cycle thinking regarding the overall impacts of the generation and

[233] Best Available Techniques (BAT) Reference Document on Surface Treatment Using Organic Solvents including Preservation of Wood and Wood Products with Chemicals

[234] e.g. with respect to energy requirement and quality of regenerates

management of such waste as specified in Article 4 (2) WFD. Increasing the awareness among solvent users that the solvents contained in their off-gases are potentially too valuable to be oxidised could be a starting point.

France is to our knowledge the first MS to have introduced **end-of-waste criteria** for regenerated chemicals which also include solvents. The impact of these criteria on spent solvent recycling should be followed closely. For the MS where end-of-waste criteria are set on a case-by-case basis a common database as proposed by MiW/IMPEL (2019) is deemed beneficial to improve information exchange and transparency. Also the study on Member States' practices on by-product and end-of-waste commissioned by DG ENV is expected to provide valuable input.

As one practical point hindering the acceptance of regenerated solvents the lack of assignable REACH registration numbers to recovered solvents exempted from registration was identified as a barrier (ESRG 2019, see Chapter 25 iv). The **development of a methodology to identify regenerated solvents which are exempt from REACH registration** with a substitute number or other appropriate identification could be explored as a means to improve their acceptance (subject as appropriate to requirements on sameness, quality, etc.).

A general aspect which should be taken into account when developing the solvent recycling sector is the **dynamics** of solvent production and use with respect to feedstock and applied technologies. The continued engagement in improved **statistical reporting** is valuable in order to enhance the tracking of waste streams and the confidence in the provided numbers. In this context the potential of the solvent balances of solvent-using companies required by the IED as well as of the ePRTR for aggregated statistical reporting could be explored (see Chapter 23.2).

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27 Annexes

27.1 Annex I

Table 27-1 CN codes for oils placed on the market

CN codes for oils	
27101971	LUBRICATING OILS AND OTHER PREPARATIONS CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENTS OF THE PREPARATIONS, FOR UNDERGOING A SPECIFIC PROCESS AS DEFINED IN ADDITIONAL NOTE 5 TO CHAPTER 27
27101975	LUBRICATING OILS AND OTHER PREPARATIONS CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENTS OF THE PREPARATIONS, FOR UNDERGOING CHEMICAL TRANSFORMATION (EXCL. SPECIFIC PROCESSES SPECIFIED IN ADDITIONAL NOTE 5 TO CHAPTER 27)
27101981	MOTOR OILS, COMPRESSOR LUBE OILS AND TURBINE LUBE OILS CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENTS OF THE PREPARATIONS (EXCL. FOR UNDERGOING CHEMICAL TRANSFORMATION)
27101983	LIQUIDS FOR HYDRAULIC PURPOSES CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENTS OF THE PREPARATIONS (EXCL. FOR UNDERGOING CHEMICAL TRANSFORMATION)
27101987	GEAR OILS AND REDUCTOR OILS CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENT OF THE PREPARATIONS (EXCL. FOR UNDERGOING CHEMICAL TRANSFORMATION)
27101991	METALWORKING COMPOUNDS, MOULD-RELEASE OILS, ANTI-CORROSION OILS CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENT OF THE PREPARATIONS (EXCL. FOR UNDERGOING CHEMICAL TRANSFORMATION)
27101993	ELECTRICAL INSULATING OILS CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENT OF THE PREPARATIONS (EXCL. FOR UNDERGOING CHEMICAL TRANSFORMATION)
27101999	LUBRICATING OILS AND OTHER HEAVY OILS AND PREPARATIONS N.E.S., CONTAINING BY WEIGHT >= 70% OF PETROLEUM OILS OR OF OILS OBTAINED FROM BITUMINOUS MINERALS, THESE OILS BEING THE BASIC CONSTITUENTS OF THE PREPARATIONS (EXCL. FOR UNDERGOING CHEMICAL TRANSFORMATION)
27139090	RESIDUES OF PETROLEUM OIL OR OF OIL OBTAINED FROM BITUMINOUS MINERALS (EXCL. FOR THE MANUFACTURE OF CARBON OF HEADING 2803, PETROLEUM COKE AND PETROLEUM BITUMEN)
34031910	LUBRICANT PREPARATIONS, INCL. CUTTING-OIL PREPARATIONS, BOLT OR NUT RELEASE PREPARATIONS, ANTI-RUST OR ANTI-CORROSION PREPARATIONS AND MOULD-RELEASE PREPARATIONS, BASED ON LUBRICANTS AND CONTAINING, AS NON-BASIC CONSTITUENTS, >= 70% PETROLEUM OIL OR BITUMINOUS MINERAL OIL BY WEIGHT (EXCL. PREPARATIONS FOR THE TREATMENT OF TEXTILES, LEATHER, FURSKINS AND OTHER MATERIALS)
34031980	LUBRICATING PREPARATIONS, INCL. CUTTING-OIL PREPARATIONS, BOLT OR NUT RELEASE PREPARATIONS, ANTI-RUST OR ANTI-CORROSION PREPARATIONS AND MOULD-RELEASE PREPARATIONS, BASED ON LUBRICANTS, CONTAINING, BY WEIGHT, < 70% OF PETROLEUM OIL OR OIL OBTAINED FROM BITUMINOUS MINERALS (EXCL. PREPARATIONS FOR THE TREATMENT OF TEXTILE MATERIALS, LEATHER, FUR SKINS OR OTHER MATERIALS, AND LUBRICANTS HAVING A BIO-BASED CARBON CONTENT OF AT LEAST 25% BY MASS AND WHICH ARE BIODEGRADABLE AT A LEVEL OF AT LEAST 60%)

27.1.1 Waste Oil Reporting Format

Figure 27-1 Reporting on data on the placing on the market of mineral and synthetic lubrication and industrial oils and on the treatment of waste oils (Table 1)

	1	2	3		4		5		6		7		8		9	
	Oils placed on the market (5) (t)	Waste oil generated (6) (dry oil) (t)	Separately collected (7) waste oils (t)		Exported (8) waste oils (t)		Imported (9) waste oils (t)		Regeneration (10) (t)		Other recycling (11) (t)		Energy recovery (12) (R1) (t)		Disposal (13) (t)	
			Incl. water	Dry oil (14)	Incl. water	Dry oil (14)	Incl. water	Dry oil (14)	Incl. water	Dry oil	Incl. water	Dry oil	Incl. water	Dry oil	Incl. water	Dry oil
Engine and gear box oils (1)																
Industrial oils (2)																
Industrial oils (emulsions only) (3)																
Oil and concentrates from separation (4)																

Dark shaded boxes: reporting is not applicable.

(1) Including engine oils and gear oils (automotive, aviation, marine, industrial and other sectors); excluding greases and bilge oils.
(2) Including machine oils, hydraulic oils, oils for turbines, transformer oils, heat transmission oils, compressor oils, base oils; excluding greases and oils used for emulsions.
(3) Including metal working oils; in case national reporting does not distinguish industrial oils used in emulsions or otherwise, aggregated data on industrial oils may be provided and shall be specified in row 'industrial oils'.
(4) Only waste oils under code 190207* of Decision 2000/532/EC.
(5) Oils placed on the market in a Member State taking into account export losses (e.g. export of passenger cars) and import gains (e.g. imports of passenger cars).
(6) Amount of waste oils taking into account handling losses and losses during use. Amounts of waste oil generated may be calculated based on national statistics or by using the reference values listed in Table 4.
(7) Waste oils separately collected. In case collected waste oils are quantified by volume, the corresponding mass is determined by applying a conversion factor of 0,9 tonnes/m³.
(8) Waste oil exported to another country (considering the waste categories set out in Regulation (EC) No 1013/2006).
(9) Waste oil generated in another country and imported from that country (considering the waste categories set out in Regulation (EC) No 1013/2006).
(10-13) Amounts reported shall relate to the waste oil separately collected. The sum of the values for dry oil in columns 6 to 9 should be equal to the sum of the values for dry oil in column 3 adjusted for exported and imported waste oils (column 3 – column 4 + column 5 = column 6 + column 7 + column 8 + column 9).
In accordance with the definition of regeneration of waste oils in Article 3(18) of Directive 2008/98/EC and excluding regenerated oils used for energy recovery or as fuels.
(11) Recycling other than regeneration, e.g. as flux oil.
(12) Including use of recovered oils as fuel, in accordance with the definition of recovery in Article 3(15) of Directive 2008/98/EC.
(13) Disposal operation D10 Incineration on land as laid down in Annex I of Directive 2008/98/EC.
(14) Waste oil excluding water content. The dry oil content is determined by measuring the water content. For waste oils other than emulsions, the dry content may alternatively be determined on the basis of a water content of 8 %. For dry oil in emulsions of industrial oils the dry content may alternatively be determined on the basis of a water content of 90 %.

Official Journal of the European Union 20.6.2019

Source: Official Journal of the European Union, 20.06.2019

Figure 27-2 Reporting on data on the treatment of waste oils (Table 2)

1	2	3	4	5
Type of output from recovery	Regeneration (1) (t)	Other recycling (t)	Energy recovery or reprocessing into materials that are to be used as fuels (including regenerated oils used as fuel) (t)	Disposal (D10) (t)
Regenerated base oil – group I (2) (3)				
Regenerated base oil – group II (4)				
Regenerated base oil – group III (5)				
Regenerated base oil – group IV (6)				
Recycled products (7) (specify)				
Fuel products for off-site energy recovery – Light fuel oil				
Fuel products for off-site energy recovery – Distillate fuel oil				
Fuel products for off-site energy recovery – Heavy fuel oil				
Fuel products for off-site energy recovery – Recovered fuel oil				
Fuel products for off-site energy recovery – Processed fuel oil				
On-site energy recovery (8)				
Other (specify and add rows as needed)				

Dark shaded boxes: Reporting is not applicable.

(1) Amount of regenerated oils. The sum of the entries in Column 2 of table 2 divided by the sum of the entries in column 6 of Table 1 corresponds to the conversion efficiency of oil regeneration.
(2) Base oil group I contains less than 90 % saturates and/or more than 0,03 % sulphur and has a viscosity index greater than or equal to 80 and less than 120.
(3) In case national reporting does not distinguish groups I-IV, aggregated data on regenerated base oils may be provided and shall be specified in row 'Other'.
(4) Base oil group II contains more than or equal to 90 % saturates and less than or equal to 0,03 % sulphur and has a viscosity index greater than or equal to 80 and less than 120.
(5) Base oil group III contains more than or equal to 90 % saturates and less than or equal to 0,03 % sulphur and has a viscosity index greater than or equal to 120.
(6) Base oil group IV are polyalphaolefins. Base oil not included in groups I-IV shall be specified in row 'Other'.
(7) Includes recycled products from other recycling of waste oils reported under column 7 of Table 1.
(8) On-site energy recovery means recovery of waste oils through internal energy consumption e.g. in a refinery.

9 EN Official Journal of the European Union L 163/95

Source: Official Journal of the European Union, 20.06.2019

Figure 27-3 Reporting on data on the placing on the market of mineral and synthetic lubrication and industrial oils and treatment of waste oils other than those listed in Table 1 (Table 3)

	1		2		3		4		5		6		7	
	Collected (1) Waste Oils (t)		Exported (2) Waste Oils (t)		Imported (3) Waste Oils (t)		Disposal (4) (D10) (t)		Regeneration (t) (5)		Other recycling (6) (t)		Energy recovery(t) (7)	
	Incl. water	Dry oil	Incl. water	Dry oil	Incl. water	Dry oil	Incl. water	Dry oil	Incl. water	Dry oil	Incl. water	Dry oil	Incl. water	Dry oil
Process oils														
Industrial oils not lubricating														
Greases														
Extracts from lubricant refining														
Bilge oils														

Light shaded boxes: Reporting is voluntary.
(1-7) See columns 3 to 9 in Table 1, and the corresponding Notes, for explanations of the terms used.

EN

Official Journal of the Europe

Source: Official Journal of the European Union, 20.06.2019

Figure 27-4 Reference values for the calculation of generated waste oil (Table 4)

	1
	Fraction of oils placed on market (%)
Engine and gear box oils	
Engine oils	52
Gear box oils	76
Industrial oils	
Machine oils	50
Hydraulic oils	75
Turbine oils	70
Transformer oils	90
Heat transmission oils	90
Compressor oils	50
Base oils	50
Metal working oils used in emulsions	49

Source: Official Journal of the European Union, 20.06.2019

27.1.2 Quality Check Report

Figure 27-5 Information on oils placed on the market and waste oils

1. Data collection methods (the relevant column should be marked with a cross, the last column should be filled-in)

Data collection methods/Data set	Administrative data	Surveys	Electronic registry	Data from waste operators	Data from extended producer responsibility schemes	Other (specify)	Detailed description of the methodology
Oils placed on the market							
Collected waste oils							
Regeneration of waste oils							
Other recycling of waste oils							
Energy recovery of waste oils							
Disposal of waste oils							

Add rows for the treatment of specific types of waste oil as appropriate

2. Description of the methodology used to determine the amount of waste oil generated

3. Description of the method used to determine the dry oil content of the waste oil (e.g. chemical analysis of the water content, expert knowledge, etc.)

4. Description of the outputs of treated waste oils reported under the category 'other recycling' and an indication of their amounts

5. Description of the method used to determine the amount of base oils used as fuel

6. Data on waste oil treatment outside the Member State

7. Detailed description of the specific measures for quality control and traceability of waste oils, in particular, as regards monitoring and validation of data

8. Description of the data sources for treatment of waste oils in another Member State or outside the Union (e.g. Regulation (EC) No 1013/2006 or primary data from the treatment operator) and the quality of the data

9. Description of any difficulties in collecting data from treatment operators located in another Member State or outside the Union

10. Description of measures to ensure that the exporter of waste oils outside the Union can prove that the shipment of waste complies with the requirements of Regulation (EC) No 1013/2006 and that the treatment of waste outside the Union took place in conditions that are broadly equivalent to the requirements of the relevant Union environmental law

11. Accuracy of the data

11.1. Description of main issues affecting the quality and accuracy of data on the generation, collection and treatment of waste oils, including errors related to sampling, coverage, measurement, processing and non-response

11.2. Completeness of the data collection on mineral and synthetic lubrication and industrial oils and waste oils

Detailed information on how the sources of data cover all the amounts of mineral and synthetic lubrication and industrial oils placed on the market and waste oils collected and treated, and on any amounts added by using estimates, including how the estimates are determined and what share of the total amount of the respective data set they account for.

11.3. Differences from previous reference year's data

Significant methodological changes in the calculation method for the current reference year in relation to the calculation method applied for previous year(s).

Explanation detailing the causes of the tonnage difference (which waste oils, sectors or estimates have caused the difference, and what the underlying cause is) for any category of waste oils treated which shows a greater than 10 % variation from the data submitted for the previous reference year.

Waste oil category and treatment	Variation (%)	Main reason for variation

Add rows as appropriate

III. Confidentiality

Justification to withhold the publication of specific parts of this report where that is requested.

IV. Main national websites, reference documents and publications

This includes reports addressing aspects of the data quality, coverage or other aspects of enforcement such as reports on best practice on waste oil collection and treatment, and reports on import, export or losses of oil.

Source: Official Journal of the European Union, 20.06.2019

Table 27-2 List of Waste (LoW) codes to be included in waste oil reporting

LoW codes	Waste oils categories
	Engine and gear box oils
130204*	mineral-based chlorinated engine, gear and lubricating oils
130205*	mineral-based non-chlorinated engine, gear and lubricating oils
130206*	synthetic engine, gear and lubricating oils
130207*	readily biodegradable engine, gear and lubricating oils
130208*	other engine, gear and lubricating oils
	Industrial oils
120106*	mineral-based machining oils containing halogens (except emulsions and solutions
120107*	mineral-based machining oils free of halogens (except emulsions and solutions)
120110*	synthetic machining oils
120119*	readily biodegradable machining oil
130101*	hydraulic oils, containing PCBs
130109*	mineral-based chlorinated hydraulic oils
130110*	mineral based non-chlorinated hydraulic oil
130111*	synthetic hydraulic oils
130112*	readily biodegradable hydraulic oils
130113*	other hydraulic oils
130301*	insulating or heat transmission oils containing PCBs
130306*	mineral-based chlorinated insulating and heat transmission oils other than those mentioned in 13 03 01
130307*	mineral-based non-chlorinated insulating and heat transmission oils
130308*	synthetic insulating and heat transmission oils
130309*	readily biodegradable insulating and heat transmission oils
130310*	other insulating and heat transmission oils

LoW codes	Waste oils categories
Industrial oils (emulsions only)	
120108*	machining emulsions and solutions containing halogens
120109*	machining emulsions and solutions free of halogens
130104*	chlorinated emulsions
130105*	non-chlorinated emulsion
130802*	other emulsions
Oil and concentrates from separation	
190207*	oil and concentrates from separation

Source: compiled by Oeko-Institut

27.1.3 Guidance document

The guidance document shall support MS correctly using the reporting format provided thereby enabling the provision of quantitative and qualitative data on (waste) oil placed on the market (PoM), its collection and treatment for different lubricant/waste oil categories. It also intends to provide guidance on how to draft the quality check report associated to the reporting format. The main aim of the guidance document is to guarantee that data provided is comparable between MS and that data is consistent. In the following subsections data reporting according to Tables 1 to 4 of the official reporting format in the Commission Implementing Decision (EU) 2019/1004, Annex VI, are addressed.

27.1.3.1 Elements for guidance on how to complete the reporting table Figure 27-1 (Table 1)

This section specifies how to generate/collect the data for columns 1 to 9.

When reporting waste oil data in columns 3 to 9 only the list of waste (LoW) codes as listed and grouped in Table 27-2 shall be considered. Table 27-2 also differentiates LoW codes to be linked to:

- row 'Engine and gear box oils' (130204 to 130208);
- row 'Industrial oils' (120106 to 130310);
- row 'Industrial oils (emulsions only' (120108 to 130302) and
- row 'Oil and concentrates from separation' (190207).

Emulsions should be separately reported as their huge volumes would distort reporting on other industrial oils.

Column 1: Lubricant oils not producing waste oils should not be included in column 1. This includes process oils, industrial oils not lubricating, greases, extracts from lubricant refining and marine bilge oils. These oils should not be included in Table 1 but can be voluntarily included in Table 3.

If possible, please indicate if for any reason excluding any of these lubricant oils not producing waste oils should be not possible.

If possible, please also explain if any additional lubricant oil not listed in footnotes ([1]) to ([3]) is included in one of rows 1 to 3.

Column 1, 'Engine and gear box oils' (row 1):

The generation and collection of bilge oils resulting from collected and treated bilge water is to be reported, when available, in the last row of Table 3 and not in Table 1.

The amounts of marine oil placed on the market, collected and treated should be reported in row 1 of Table 1. It is acknowledged that in a port, the distinction between the national and international origin of the marine oil is expected to be complicated.

If specific data on marine oils placed on the market or collected (other than bilge oil) should be available separately, these amounts can be voluntarily reported in section 11.1 of the quality check report and should be explained in the methodological report including if possible, information on a potential international origin of marine oil / waste oil.

Reporting of lubricant oils placed on the market should already take into account exports and imports of lubricant oils (e.g. through imports or exports of vehicles). Please explain in the methodological report if such imports/exports occur and how they are taken into account.

Column 2, 'Waste oil generated': Waste oil generated considers unavoidable losses. Therefore, the collectable amount of waste oil should be reported in column 2. This amount represents a theoretical figure which has to be calculated (based on national approaches or on the return rates in Table 4).

Please explain how the amounts of waste oil generated were derived. Please explain separately for each figure in rows 1 to 3 (column 2).

Column 3, 'Separately collected waste': The amounts to be reported in column 3 represent the actual collected amount of waste oil. The actual quantity collected is expected to be in the order of magnitude of the calculated amount of collectable waste oil (in column 2). 'Separate collection' means the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment.

Columns 6 to 9: In columns 6 to 9 the input amounts into the treatment processes should be reported. The output of the treatment is subject of Table 2.

Column 6, 'Regeneration': Under 'Regeneration' only the input into re-refineries in which the main products were base oils that were used in a lubricant application (not as a fuel product or in energy recovery) should be reported. Exclude input which results in regenerated / recovered oils completely going to energy recovery or used as fuels (see footnotes 10 and 12 in Table 1) or completely going wholly to a combination of energy recovery or used as fuels or used as flux oil. Waste oil treatment which completely results in oil, e.g. used as flux oil to modify viscosity of bituminous binders, should be reported in column 7 "other recycling". To clarify, if input of waste oils to a treatment process results in an output mix of base oils (used in lubrication applications) as well as fuel products and/or flux oils, such waste oils should be reported as input in Column 6 (with the output of that process being split across at least Column 2 and Columns 3 or 4 of Table 2).

27.1.3.2 Elements for guidance on how to complete the reporting table Figure 27-2 (Table 2)

In Table 2, columns 2, 3 and 4, generally the **outputs of treatment processes** and of them the main products to be considered are listed in the rows of the table. Column 5 in Table 2 considers D10 incineration on land. In case of **incineration the input (dry oil) and not the output** should be reported in column 5 (since there is no material output (as a product)).

Column 2 (Table 2) relates to column 6 in Table 1. Column 3 (Table 2) corresponds to column 7 in Table 1. Column 4 (Table 2) relates to column 8 in Table 1 but will also include fuel products, listed in column 1, obtained from waste oil regeneration and destined to energy recovery / use as fuel.

Column 2 (Table 2) Regeneration:

Regenerated base oils present the main output of the regeneration (re-refining) process of waste oil. Currently only base oils of groups I to III are produced as products. In column 2 the amounts of each base oil group should be reported.

The base oil groups are classified into five groups according to the classification of the American Petroleum Institute (API). This categorisation is based on the following main criteria: percentage of saturates, sulphur content and viscosity index. The API groups and their characteristics are presented in the following table and are referred to (group I to IV) in column 1 in Table 2.

Category	Sulphur content %		Saturates %	Viscosity index
Group I	>0.03	and/or	<90	80 to 120
Group II	<0.03	and	>90	80 to 120
Group III	<0.03	and	>90	> 120
Group IV	polyalphaolefins (PAOs)			
Group V	All other base oils not included in Groups I to IV			

Should no information on the level of the individual base oil groups be available, the aggregated total amount of regenerated base oil should be reported in row 'Other'. The total sum of all entries in column 2 represents the total output of all base oil resulting from the total input into waste oil regeneration in column 6 in Table 1.

The focus of the reporting is on regenerated base oil but other products resulting from re-refining (e.g. fuels, asphalt flux) should also be reported in the corresponding cells of the table. The resulting amount and group of regenerated base oil will depend on the composition of the waste oil input into the re-refining process and on the re-refining treatment available.

In case regenerated base oil should be burned as a fuel, this amount of base oil should be reported in column 4 of Table 2 to help ensure no double counting of this material. This amount of regenerated base oil used as a fuel shall be deducted from column 2 and only be reported in column 4. Base oils used as fuel should be reported according to their base oil group I to IV (row group I to row group IV) or if no separate information is available as an aggregate in row 'Other'.

Column 3 (Table 2) Other recycling:

The output from other recycling (e.g. flux oil) (in column 7 in Table 1) should be reported for each product separately in column 3 (Table 2). The amount of the product should be reported in row 'Recycled products'. Should there be more than one product additional products can be added in row 'Other'.

Column 4 (Table 2) Energy recovery:

In column 4 amounts of fuel products resulting as output from waste oil treatment processes should be reported. All output independent of whether it is used for energy recovery in e.g. cement kiln, lime works, power plant etc. or used as a fuel for ships or in on-site energy recovery in regeneration or other recycling operations, should be recorded. The fuel should be differentiated into 'Light fuel oil', 'Distillate fuel oil', etc. Should a distinction be not possible, an aggregate should be reported in row 'Other'. In case another category of fuel applies, additional rows should be added and the fuel type should be specified.

Overall Balance Table 1 / Table 2

Similar to the 'mass balancing requirement' footnote 10 in Table 1, the combined total amount of outputs reported in all rows in Table 2 (column 2 + column 3 + column 4 + column 5), should roughly equal the combined total amount of (dry) waste oil inputs reported in all rows of Table 1 (column 6 + column 7 + column 8 + column 9).

27.1.3.3 Elements for guidance on how to complete the reporting table Figure 27-3 (Table 3)

In Table 3, additional mineral oils (and resulting waste oils) other than those listed in Table 1 should be reported.

Table 3 mainly considers mineral oils not producing waste oil or only small amounts of collectable waste oils. Due to international shipping traffic bilge oils can originate from many different countries and therefore amounts collected will differ and not be traceable to the amounts of any oil placed on the market in a given country. Consequently, in this table there is no column for the reporting of the oil placed on the market given it will not be useful for comparative purposes.

Columns 1 to 7 correspond to columns 3 to 9 in Table 1 and should be filled in accordingly.

27.1.3.4 Elements for guidance on how to use Table 4 in Figure 27-4

Table 4 presents specific return rates for the various lubricant oils. Return rates are the share of the lubricant oil placed on the market that is considered to be collectable. When multiplying the amount of a lubricant oil placed on the market with its specific return rate, the waste oil generated (collectable) of the specific application of the lubricant oil results.

The return rates in Table 4 are to a large extent based on German experience (UBA 2016). These figures are to be applied if no country-specific figures are used.

27.1.3.5 Elements for guidance on how to complete the quality check report (Figure 27-5)

The analysis of the MS questionnaires did not reveal any notable difficulties on the part of the MS in answering the questions related to the quality check report.

Below those questions are addressed that are most likely to cause difficulties in answering them.

1. Data collection methods:

The rows of the table are based on the columns of Table 1 of the waste oil reporting format.

6. Data on waste oil treatment outside the Member State:

This question refers to the amount of waste oil exported to another country, and therefore subject to provisions of the Regulation (EC) 1013/2006, reported in column 4 of Table 1 of the waste oil reporting format. Please provide data on the share of each treatment option (regeneration, other recycling, energy recovery and disposal) of the total waste oil exported.

11.1 Description of main issues affecting the quality and accuracy of data on generation, collection and treatment of waste oils:

Please also describe if bio lubricant oils are included in the data. If yes, please estimate their share of lubricant oils placed on the market as well as of the collected waste oils.

Please also describe, if available, the share of marine oil reported in the aggregated figure of motor and gear-box oil reported in row 1 of Table 1.

11.2 Completeness of data collection on mineral and synthetic lubrication and industrial oils and waste oils:

Please also describe if data is only available from one or more EPR schemes / PRO systems, but additional other organisations / companies are involved in waste oil management and their data is missing.

27.2 Annex II

Table 27-3 Extra EU-28 trade (imports–exports) of lubricants; years 2012 to 2018, 1000 t, (negative figures = net export)

MS	2012	2012	2012	2013	2013	2013	2014	2014	2014	2015	2015	2015	2016	2016	2016	2017	2017	2017	2018	2018	2018
	intra	extra	total	INTRA	EXTRA	total	INTRA	EXTRA	total	INTRA	EXTRA	total	INTRA	EXTRA	total	INTRA	EXTRA	total	INTRA	EXTRA	total
AT	17	13	30	58	8	66	70	15	85	91	12	102	119	4	123	173	7	180	149	13	162
BE	-84	127	43	-151	184	33	-222	163	-59	-311	282	-29	-283	290	7	-112	376	263	-95	184	89
BG	-13	-895	-908	25	-809	-784	79	-171	-92	38	10	48	31	17	48	25	19	44	36	12	48
CY	8	1	9	6	1	7	7	1	7	8	1	8	8	1	8	8	1	8	8	1	8
CZ	70	-4	65	66	-5	61	72	-3	69	87	-5	82	31	-6	25	125	-5	119	128	-5	123
DE	335	-242	94	165	-200	-35	104	-179	-75	62	116	178	173	-19	154	376	-95	281	-62	-63	-124
DK	35	-1	34	38	-3	35	8	-2	5	6	-2	4	25	-5	20	32	-3	29	21	-3	18
EE	10	8	18	8	12	20	5	19	24	4	5	10	9	6	15	11	3	14	11	7	18
ES	144	-97	47	-90	-115	-205	-54	-104	-159	-294	-174	-468	-462	-264	-726	-778	-205	-983	-890	-272	-1162
FI	-176	-84	-260	-181	-95	-276	-204	-79	-283	-172	-49	-222	-206	-68	-274	-201	-81	-282	-196	-83	-279
FR	26	-282	-257	-77	-337	-414	-118	-271	-389	358	-119	240	45	-156	-110	148	-171	-23	184	-38	146
GB	-142	-203	-345	366	-104	262	106	-359	-253	183	-219	-36	135	-130	5	152	-252	-100	102	-189	-87
GR	10	-209	-199	47	-209	-162	31	-208	-177	41	-230	-189	18	-202	-184	14	-198	-184	6	-190	-184
HR	257	157	415	28	206	235	58	297	356	51	238	288	45	323	368	45	147	193	51	57	108
HU	30	-47	-17	29	-35	-5	131	-28	103	149	-34	115	64	-39	24	-12	-39	-50	74	-40	34

MS	2012	2012	2012	2013	2013	2013	2014	2014	2014	2015	2015	2015	2016	2016	2016	2017	2017	2017	2018	2018	2018
IE	29	0	29	31	0	31	31	0	32	32	0	32	31	0	32	34	0	35	33	0	33
IT	-64	-748	-811	-30	-732	-763	-6	-813	-819	-22	-800	-822	-92	-723	-815	-55	-838	-893	28	-793	-764
LT	29	-13	16	32	107	139	37	49	86	23	4	27	6	3	9	5	-2	3	1	6	7
LU	8	0	8	8	0	8	8	0	8	8	0	8	9	0	9	8	0	8	10	0	10
LV	7	12	19	5	16	21	1	14	15	-10	23	13	-6	28	22	-15	26	11	-1	22	21
MT	4	0	4	3	0	4	5	0	5	4	0	5	5	0	6	4	0	4	4	0	4
NL	-666	129	-537	-449	162	-287	-429	215	-214	-505	-56	-561	-16	49	33	-42	-30	-72	-146	340	194
PL	-263	-75	-337	-271	-77	-349	-323	-88	-411	-270	-96	-366	-348	-77	-424	-120	-61	-181	-116	-103	-219
PT	35	-20	15	29	-22	7	64	14	77	48	-46	2	43	27	70	-28	-27	-55	-11	-15	-26
RO	85	12	97	86	7	93	73	7	80	-13	7	-6	-9	0	-9	-7	-5	-11	82	2	83
SE	-86	-48	-134	-186	-44	-230	-214	-47	-261	-125	-49	-174	-103	-39	-142	-15	-38	-52	-45	-39	-84
SI	21	-3	18	24	-6	17	23	-4	18	33	-4	29	26	-8	18	32	-9	23	25	-9	16
SK	50	1	51	-6	1	-5	-128	0	-129	-160	1	-159	-35	0	-35	-29	0	-29	-60	0	-61
EU-28	-282	-2513	-2794	-387	-2089	-2475	-787	-1564	-2351	-657	-1184	-1841	-736	-988	-1724	-219	-1480	-1699	-670	-1197	-1867

Source: Eurostat COMEXT, codes 27101971, 27101975, 27101981, 27101983, 27101987, 27101991, 27101993, 27101999, 27139090, 34031910, 34031980; extracted 14.5.2019; compilation Oeko-Institut

Table 27-4 Lubricants and waste oil data by MS in tonnes; years 2014 to 2018; different data sources

Source	MS	Year	Consumption	Collectable	Collectable dry	Collected	Collected dry	Energy recovery sum	Cement	Power plant etc.	Fuel	Re-ref.	Other use	Disposal	Export re-ref.	Export other
GEIR 2019	AT	2014	70000	35000	32900	33000	31020	10000		10000					23000	
GEIR 2019	AT	2017	69900	38000	35720	35000	32900	10000		10000					25000	
GEIR 2019	AT	2018	66700	37000	34780	35000	32900	10000		10000					25000	
Austria 2015	AT	2014				33100								15800		
GEIR 2019	BE	2014	110000	53191	50000	47872	45000	0			7000				38000	
GEIR 2019	BE	2017	77000	48936	46000	47234	44400	0			2000				42400	
GEIR 2019	BE	2018	74000	48511	45600	47872	45000	0			2000				43000	
Belgium 2017	BE	2014	69074	49526	49526	64088	43531									
Belgium 2017	BE	2015	71415	51205	51205	64566	43530									
Belgium 2017	BE	2016	72326	51848	51848	64037	40629									
Belgium 2017	BE	2017	70314	45142	45142	65498	42283	2871					2871		39239	
GEIR 2019	BG	2014	32000	13000	12220	8000	7520	0			1000	7000				
GEIR 2019	BG	2017	34000	17000	15980	10000	9400	0			2000	8000				
GEIR 2019	BG	2018	31000	16000	15040	10000	9400	0			2000	8000				
GEIR 2019	HR	2014	24000	17000	15980	14000	13160	10000	10000		4000					
GEIR 2019	HR	2017	29000	15000	14100	14000	13160	10000	10000		4000					
GEIR 2019	HR	2018	29000	15000	14100	14000	13160	10000	10000		4000					
Croatia 2017	HR	2014	22791	11396	11396	5753	5465	0								
Croatia 2017	HR	2015	32786	16393	16393	5390	5121	0								
Croatia 2017	HR	2016	34881	17441	17441	7033	6681	0								
Croatia 17	HR	2017	34575	17288	17288	6407	6087	0								
GEIR 2019	CY	2014	6000	3000	2820	3000	2820	0			3000					
GEIR 2019	CY	2017	4000	2000	1880	2000	1880	0			2000					
GEIR 2019	CY	2018	4000	2000	1880	2000	1880	0			2000					
GEIR 2019	CZ	2014	110000	50000	47000	40000	37600	10000		10000			15000		10000	5000
GEIR 2019	CZ	2017	85000	47000	44180	45000	42300	20000	5000	15000	6000		10000		4000	5000

Source	MS	Year	Consumption	Collectable	Collectable dry	Collected	Collected dry	Energy recovery sum	Cement	Power plant etc.	Fuel	Re-ref.	Other use	Disposal	Export re-ref.	Export other
GEIR 2019	CZ	2018	83000	46000	43240	45000	42300	20000	5000	15000	6000	0	10000		4000	5000
MS survey 2019	CZ	2017				109654	42201	4695				1812	5518	1000		
Czech 2017	CZ	2017				38841	36511									
GEIR 2019	DK	2014	50000	24000	22560	20000	18800	0				20000				
GEIR 2019	DK	2017	49000	26000	24440	19000	17860	0				19000				
GEIR 2019	DK	2018	51000	27000	25380	19000	17860	0				19000				
MS survey 2019	DK	2014	37605	24219	24219	43345	18952	1528				8565	1768	1955		
MS survey 2019	DK	2015	35341	21509	21509	35682	17232	1774				11868	389	2302		
MS survey 2019	DK	2016	44210	28524	28524	30763	14843	1392				10635	282	2314		
MS survey 2019	DK	2017	46877	30203	30203	43094	16290	908				13094	87	2130		
Denmark 2014	DK	2014	51320			28823	21954									
Denmark 2017	DK	2017	51320													
GEIR 2019	EE	2014	4000	2000	1880	1500	1410	1500	1500							
GEIR 2019	EE	2017	7000	3500	3290	2000	1880	2000	2000							
GEIR 2019	EE	2018	7000	3500	3290	2000	1880	2000	2000							
MS survey 2019	EE	2014		2371	2371	2179	1732	210				1	643			
MS survey 2019	EE	2015		2604	2604	2360	2011	89				1	65	1		
MS survey 2019	EE	2016		2776	2776	2178	1869	347				1	25	7		
MS survey 2019	EE	2017		2725	2725	2603	2222	810				16	4			
GEIR 2019	FI	2014	50000	24000	22560	22000	20680	2000		2000		20000				
GEIR 2019	FI	2017	58000	30000	28200	22000	20680	2000		2000		20000				
GEIR 2019	FI	2018	55000	28000	26320	22000	20680	2000		2000		20000				
Finland 2014	FI	2011	54000	30240	30240	23000	21620									
GEIR 2019	FR	2014	570000	256000	240640	211000	198340	38000	26000	12000	10000	118000	7000		38000	
GEIR 2019	FR	2017	554000	277000	260380	201000	188940	46700	31700	15000	8900	120000	7100		18300	
GEIR 2019	FR	2018	552000	277000	260380	201000	188940	49000	31000	18000	16000	120000			11000	
CPL 2017	FR	2015	567712													
CPL 2017	FR	2016	562712													

Source	MS	Year	Consumption	Collectable	Collectable dry	Collected	Collected dry	Energy recovery sum	Cement	Power plant etc.	Fuel	Re-ref.	Other use	Disposal	Export re-ref.	Export other
France 2018	FR	2018	551999					0								
France 2017	FR	2017	535575			201155	188937	46791	31724	15067	8974	119426		899	18332	
GEIR 2019	DE	2014	1035000	494681	465000	491489	462000	53191		53191	145745	238298	10638		11702	31915
GEIR 2019	DE	2017	1032000	468085	440000	471200	440000	72822		72822	67681	283577	31056		7496	8567
GEIR 2019	DE	2018	1011000	461702	434000	461500	434000	74435		74435	69119	256271	45725		15950	
MS survey 2019	DE	2014	1049151	474202	474202											
MS survey 2019	DE	2015	1026606	471160	471160											
MS survey 2019	DE	2016	1067178	446768	446768											
MS survey 2019	DE	2017	979028	443434	443434											
Own calculation, BAFA 2016, Destatis 2016	DE	2014	1090325	474199	474199	1157200	484001	30851				307149	146001			
Own calculation, BAFA 2016, Destatis 2016	DE	2015	1064884	471181	471181	1148900	485472									
Own calculation, BAFA 2016, Destatis 2016	DE	2016	1035514	446861	446861	1116600	468106	66000	66000							
Own calculation, BAFA 2016, Destatis 2016	DE	2017	1032440	443548	443548	1108700	464358	68000	68000							
UBA 2016	DE	2014	1090325	467250	467250			29783	28544	1239		296316	141151			
Zimmermann 2018	DE	2015	1064884	515609	515609			25127				301267	189215			
GEIR 2019	EL	2014	42000	25000	23500	24000	22560	0				24000				
GEIR 2019	EL	2017	50000	30000	28200	24000	22560	0				24000				
GEIR 2019	EL	2018	48000	29000	27260	24000	22560	0				24000				
MS survey 2019	EL	2014	44500	26700	26700		23634	0				23550				45
MS survey 2019	EL	2015	42720	25632	25632		22555	0				22510				45
MS survey 2019	EL	2016	46480	27870	27870		24992	0				24970				22
MS survey 2019	EL	2017	64403	34410	34410		25592	0				25570				22
Ademe 2010	EL	2007	100000	60000	60000	36550		0								
GEIR 2019	HU	2014	35000	16000	15040	12000	11280	0					12000			

Source	MS	Year	Consumption	Collectable	Collectable dry	Collected	Collected dry	Energy recovery sum	Cement	Power plant etc.	Fuel	Re-ref.	Other use	Disposal	Export re-ref.	Export other
GEIR 2019	HU	2017	65000	25000	23500	12000	11280	0			13000		12000			
GEIR 2019	HU	2018	65000	25000	23500	12000	11280	0			13000		12000			
GEIR 2019	IE	2014	35000	16000	15040	14000	13160	4000		4000	10000					
GEIR 2019	IE	2017	25000	13000	12220	13000	12220	3000		3000	10000					
GEIR 2019	IE	2018	25000	13000	12220	13000	12220	3000		3000	10000					
GEIR 2019	IT	2014	390000	180000	169200	180000	169200	0				165000				15000
GEIR 2019	IT	2017	406000	183000	172020	183000	172020	2000				181000				
GEIR 2019	IT	2018	400000	186600	175404	186600	175404	100				186500				
MS survey 2019	IT	2017	393400	181000	181000	183000	168000	610				167000	400	662		
Conou 2017	IT	2014	387000			167400	153679	16000				167000		200		
Conou 2017	IT	2015	386000			166672	153010	0				157600				
Conou 2017	IT	2016	403000			177000	162492	0				176200				
Conou 2017	IT	2017	406000			182700	167725	1100				180900		300		
GEIR 2019	LV	2014	15000	7000	6580	6000	5640	0			6000					
GEIR 2019	LV	2017	11000	5000	4700	5000	4700	0			5000					
GEIR 2019	LV	2018	10000	5000	4700	5000	4700	0			5000					
MS survey 2019	LV	2014					9565					4202				
MS survey 2019	LV	2015					8599					3325				
MS survey 2019	LV	2016					6302					3828				
MS survey 2019	LV	2017					7596					5988				
GEIR 2019	LT	2014	23000	10000	9400	5000	4700	1000	1000						4000	
GEIR 2019	LT	2017	11000	6000	5640	5000	4700	1000	1000						4000	
GEIR 2019	LT	2018	12000	6000	5640	5000	4700	1000	1000						4000	
GEIR 2019	LU	2014	7000	3000	2820	3000	2820	0							2000	1000
GEIR 2019	LU	2017	4700	3000	2820	3000	2820	0			0				3000	0
GEIR 2019	LU	2018	4700	3000	2820	3000	2820	0			0				3000	0
GEIR 2019	MT	2014	4000	2000	1880	2000	1880	0								2000
GEIR 2019	MT	2017	3500	2000	1880	2000	1880	0								2000

Source	MS	Year	Consumption	Collectable	Collectable dry	Collected	Collected dry	Energy recovery sum	Cement	Power plant etc.	Fuel	Re-ref.	Other use	Disposal	Export re-ref.	Export other
GEIR 2019	MT	2018	3500	2000	1880	2000	1880	0								2000
GEIR 2019	NL	2014	100000	48000	45120	48000	45120	0			18000				30000	
GEIR 2019	NL	2017	105000	55000	51700	53000	49820	0			3000				50000	
GEIR 2019	NL	2018	120000	60000	56400	52000	48880	0			2000				50000	
Netherlands 2017	NL	2014	194000													
Netherlands 2017	NL	2015	171000													
Netherlands 2017	NL	2016	192000													
Netherlands 2017	NL	2017	184000													
GEIR 2019	PL	2014	220000	107000	100580	90000	84600	0			50000	32000			8000	
GEIR 2019	PL	2017	226000	120000	112800	90000	84600	0			43000	35000			12000	
GEIR 2019	PL	2018	235000	123000	115620	90000	84600	0			43000	35000			12000	
POPHIN 2018	PL	2015	232112													
POPHIN 2018	PL	2016	223402													
POPHIN 2018	PL	2017	226896													
POPHIN 2018	PL	2018	234624													
GEIR 2019	RO	2014	70000	34000	31960	25000	23500	10000	10000		15000					
GEIR 2019	RO	2017	150000	78000	73320	30000	28200	10000	10000		15000				5000	
GEIR 2019	RO	2018	150000	78000	73320	30000	28200	10000	10000		15000				5000	
GEIR 2019	PT	2014	72000	32000	30080	25000	23500	0			10000				15000	
GEIR 2019	PT	2017	64000	28000	26320	26000	24440	0	0		6000	19000			1000	
GEIR 2019	PT	2018	64000	28000	26320	27000	25380	0	0		7000	20000				
MS survey 2019	PT	2014	59116	26011	26011	24978	21329					4756	6447		10126	
MS survey 2019	PT	2015	61350	26994	26994	24574	21762					14991	6771		0	
MS survey 2019	PT	2016	62092	27321	27321	25917	21666					14480	5281		1905	
MS survey 2019	PT	2017	64293	27519	27519	25771	25291					18160	5789		1342	
SIGOU 2018	PT	2014	71879			24466	21748					14882	6447			

Source	MS	Year	Consumption	Collectable	Collectable dry	Collected	Collected dry	Energy recovery sum	Cement	Power plant etc.	Fuel	Re-ref.	Other use	Disposal	Export re-ref.	Export other
SIGOU 2018	PT	2015	74244			24508	21909					14991	6771			
SIGOU 2018	PT	2016	75641			25707	23025					16385	5281			
SIGOU 2018	PT	2017	78458			26263	23791					19502	5789			
SIGOU 2018	PT	2018	80102			27246	24567					19476	4673			
GEIR 2019	SI	2014	20000	9000	8460	7000	6580	4000	4000		3000					
GEIR 2019	SI	2017	14000	7000	6580	7000	6580	4000	4000		3000					
GEIR 2019	SI	2018	14000	7000	6580	7000	6580	4000	4000		3000					
GEIR 2019	SK	2014	40000	19000	17860	14000	13160	4000	4000		10000					
GEIR 2019	SK	2017	47000	24000	22560	14000	13160	4000	4000		10000					
GEIR 2019	SK	2018	47000	24000	22560	14000	13160	4000	4000		10000					
MS survey 2019	SK	2014		10932	10932	28698	10932	429				3296	480	158		
MS survey 2019	SK	2015		7257	7257	21444	7257	362				3251	35	169		
MS survey 2019	SK	2016		9120	9120	27277	9120	97				4111	26	19		
MS survey 2019	SK	2017		11190	11190	29426	11190	996				2957	17	28		
GEIR 2019	ES	2014	331200	180000	169200	135000	126900	0			35000	90000	10000			
GEIR 2019	ES	2017	385480	200000	188000	155375	146052	0			46976	108399				
GEIR 2019	ES	2018	388240	200000	188000	163217	153424	0			47335	115884				
MS survey 2019	ES	2014	271526	146058	146058	171458	140086	43179				96908				
MS survey 2019	ES	2015	284194	153059	153059	173176	134098	27913				104592	1594			
MS survey 2019	ES	2016	311518	165697	165697	177142	137716	32554				101846	3315			
MS survey 2019	ES	2017	316872	168040	168040	191460	155117	44109				108220	3558	1825		
Sigaus 2017	ES	2014	278342			159425	126089									
Sigaus 2017	ES	2015	291670			152630	120715									
Sigaus 2017	ES	2016	298847			154206	121961									
Sigaus 2017	ES	2017	295143			170070	134508									
GEIR 2019	SE	2014	110000	50000	47000	40000	37600	0			20000				20000	
GEIR 2019	SE	2017	86000	45000	42300	40000	37600	0			20000				20000	
GEIR 2019	SE	2018	86000	45000	42300	40000	37600	0			20000				20000	

Source	MS	Year	Consumption	Collectable	Collectable dry	Collected	Collected dry	Energy recovery sum	Cement	Power plant etc.	Fuel	Re-ref.	Other use	Disposal	Export re-ref.	Export other
GEIR 2019	UK	2014	665000	305000	286700	265000	249100	0			195000	50000			20000	
GEIR 2019	UK	2017	638000	330000	310200	215000	202100	0			145000	50000			20000	
GEIR 2019	UK	2018	623000	323000	303620	215000	202100	0			145000	50000			20000	
UK 2018	UK	2014	414920													
UK 2018	UK	2015	392610													
UK 2018	UK	2016	386560													
UK 2018	UK	2017	400100													

Compiled by Oeko-Institut; some figures are recalculated for better comparison (e.g. subtracting water content)

Table 27-5 LoW codes aggregated under EWC Stat code on W013 "used oils"

W013 used oils with LoW codes		
1.3 Used oils		
	01.31 Used motor oils	
		13 02 04* mineral-based chlorinated engine, gear and lubricating oils
		13 02 05* mineral-based non-chlorinated engine, gear and lubricating oils
		13 02 06* synthetic engine, gear and lubricating oils
		13 02 07* readily biodegradable engine, gear and lubricating oils
		13 02 08* other engine, gear and lubricating oils
	01.32 Other used oils	
		05 01 02* desalter sludges
		05 01 03* tank bottom sludges
		05 01 04* acid alkyl sludges
		05 01 12* oil containing acids
		08 03 19* disperse oil
		08 04 17* rosin oil
		12 01 06* mineral-based machining oils containing halogens (except emulsions and solutions)
		12 01 07* mineral-based machining oils free of halogens (except emulsions and solutions)
		12 01 08* machining emulsions and solutions containing halogens
		12 01 09* machining emulsions and solutions free of halogens
		12 01 10* synthetic machining oils
		12 01 12* spent waxes and fats
		12 01 18* metal sludge (grinding, honing and lapping sludge) containing oil
		12 01 19* readily biodegradable machining oil

W013 used oils with LoW codes		
		13 01 04* chlorinated emulsions
		13 01 05* non-chlorinated emulsions
		13 01 09* mineral-based chlorinated hydraulic oils
		13 01 10* mineral based non-chlorinated hydraulic oils
		13 01 11* synthetic hydraulic oils
		13 01 12* readily biodegradable hydraulic oils
		13 01 13* other hydraulic oils
		13 03 06* mineral-based chlorinated insulating and heat transmission oils other than those mentioned in 13 03 01
		13 03 07* mineral-based non-chlorinated insulating and heat transmission oils
		13 03 08* synthetic insulating and heat transmission oils
		13 03 09* readily biodegradable insulating and heat transmission oils
		13 03 10* other insulating and heat transmission oils
		13 05 06* oil from oil/water separators
		20 01 26* oil and fat other than those mentioned in 20 01 25

Table 27-6 Imports and exports of waste oils (dry oil); by MS and by year (2011 to 2016), in tonnes

tonnes	Import 2011	Import 2012	Import 2013	Import 2014	Import 2015	Import 2016	Export 2011	Export 2012	Export 2013	Export 2014	Export 2015	Export 2016
Austria	1496	2778	1388	2427	2155	1823	20150	20696	19159	22518	15298	15812
Belgium	685	7866	7664	12373	13223	3172	36915	40633	46629	61086	45962	60716
Bulgaria	0	0	0	0	794	1116	0	0	0	282	316	592
Croatia	0	0	0	0	0	15	0	80	0	0	0	0
Cyprus												
Czechia							0	0	3352	7355	7166	4216
Denmark	26126	18513	8349	29272	12093	16396	7915	9860	9203	7753	3372	215
Estonia	0	339	4690	958	3303	220	334	234	203	441	570	132
Finland	11707	10289	4604	13144	656	4433	122	73	1334	1384	339	48
France	0	0	13515	11367	10582	23191	0	0	31313	56990	33836	8135
Germany	175547	153992	148709	164233	144985	160248	11854	16723	27908	38402	23229	17649
Greece	0	636	0	0	0	14674	95	24	0	5	0	0
Hungary	62	0	727	552	173	0	28	28	0	361	293	239
Ireland	1107	5075	6417	2931	0	2073	174	217	1028	1223	0	114
Italy	0	22002	5936	15467	23912	13854	0	0	350	877	1328	222
Latvia	0	161	20	0	0	0	0	0	0	163	0	0
Lithuania	1251	1951	0	0	452	0	144	254	1746	21	3003	3225
Luxembourg	5	0	0	0	0	6	3501	0	0	0	0	3384
Malta							0	0	0	0	0	2
Netherlands	12907	34629	25845	46693	3581	1469	17293	13215	18254	20415	63240	84209
Poland	0	1763	2774	2492	1334	859	0	861	1973	4814	0	691
Romania							0	0	0	11	1217	0
Portugal	0	0	0	0	4610	5540	0	862	10083	4342	1849	1678
Slovenia							1946	1923	2887	4186	2315	1484
Slovakia	108	202	83	361	0	23	0	0	0	611	357	39
Spain	6411	15729	39899	15040	0	130	989	217	203	301	117	108
Sweden	0	9802	877	1113	2327	2053	33003	29595	25911	36323	23631	17783
United Kingdom	18	139	1802	402	1360	0	28995	28167	36345	27358	39540	12852

Source: Eurostat, Transboundary Shipments of Waste (WShipR); imports: incl. imports from MS and non-EU countries; exports: incl. exports to MS and non-EU countries; waste oils incl. water

Table 27-7 Import (left) and Export (right) data by LoW code and treatment category (D1 to D11 and R1 to R12), excl. water; extract of selected MS

Country re	Disposa	European	Genera	2011	2012	2013	2014	2015	2016
Austria	D10	190207*	Y9	0	0	0	0	294	239
		130301*	Y10	0	0	0	0	0	13
		130301*	Y18	0	0	107	0	0	0
		130205*	Y8	38	21	0	0	0	0
		130205*	Y9	42	0	0	0	0	0
		130111*	Y8	0	0	0	0	0	95
		130110*	Y8	36	0	0	0	0	0
		130110*	Y9	0	22	20	0	0	0
		130104*	Y9	4	0	0	0	0	0
	D10			119	42	127	0	294	346
	D9	120109*	Y17	0	0	0	0	123	0
		120109*	Y9	172	235	172	282	45	0
	D9			172	235	172	282	168	0
	R1	190207*	Y8	0	0	0	1.327	666	59
		130208*	Y8	0	100	147	83	97	0
		130205*	Not sp	0	217	0	0	0	0
		130205*	Y8	0	223	594	37	343	66
	R1			0	540	741	1.447	1.106	125
	R12	130205*	Not sp	0	23	0	0	0	0
	R13	190207*	Y8	393	0	0	0	0	488
		130205*	Not sp	0	885	0	0	0	0
		130205*	Y8	812	899	347	698	479	798
	R13			1.205	1.784	347	698	479	1.285
	R3	120109*	Y9	0	0	0	0	0	33
	R4	120109*	Y17	0	0	0	0	108	0
		120108*	Y17	0	154	0	0	0	0
	R4			0	154	0	0	108	33
Austria	Total			1.496	2.778	1.388	2.427	2.155	1.823
Belgium	D10	130301*	Y10	102	318	97	104	17	12
		130301*	Y9	10	0	0	0	0	0
		130204*	Y8	0	0	0	0	82	0
		130101*	Y10	99	91	89	49	93	58
		130101*	Y8	0	0	0	0	33	110
		120106*	Unkno	0	0	33	17	0	0
	D10			211	409	219	170	225	180
	D14	130301*	Y10	2	15	63	147	0	0
		130301*	Y9	0	12	0	22	1	0
	D14			2	27	63	169	1	0
	D15	130301*	Y10	0	0	0	0	217	22
	D9	130506*	Y9	55	27	0	0	0	0
		130205*	Y8	0	0	0	238	0	0
		120109*	Not sp	28	20	0	0	0	0
		120109*	Unkno	0	0	20	13	0	0
		120109*	Y9	196	229	278	282	316	352

Country re	D- and R-code	LoW code	Y code	2011	2012	2013	2014	2015	2016
Austria	R1	130205*	Y8	108	212	83	0	0	38
	R9	130310*	Y8	67	34	0	0	0	106
		130307*	Y8	462	398	573	889	740	276
		130205*	Y8	19512	20053	18424	21629	14559	15391
		120109*	Y8	0	0	80	0	0	0
	R9			20042	20484	19076	22518	15298	15773
Austria	**total**			20150	20696	19159	22518	15298	15812
Belgium	D9	120109*	Y9	0	0	0	0	0	5
	R1	190207*	Y18	0	0	0	0	0	359
		190207*	Y9	0	924	5825	8461	10275	12261
		130205*	Y8	2059	645	0	0	0	0
	R1			2059	1569	5825	8461	10275	12620
	R12	130506*	Y9	0	0	0	64	129	131
		130208*	Y9	0	0	0	0	0	89
		130205*	Y8	1896	2020	77	10614	713	13242
		120107*	Y8	0	0	0	0	0	6
	R12			1896	2020	77	10678	842	13468
	R13	130205*	Y8	9968	9298	10378	11911	14479	1248
	R3	190207*	Y18	0	0	0	0	115	0
		190207*	Y8	0	0	2684	69	1499	0
		190207*	Y9	0	1113	4243	1168	31	35
	R3			0	1113	6927	1237	1644	35
	R9	190207*	Y8	0	0	1508	7841	4271	5732
		190207*	Y9	0	7583	287	7992	415	19
		130307*	Y8	0	0	227	573	721	177
		130208*	Y8	0	0	368	0	25	1900
		130205*	Not spe	13571	12179	0	0	10438	17384
		130205*	Unknov	0	0	12467	3447	0	0
		130205*	Y8	9421	6861	8566	8945	2851	7980
		130110*	Y8	0	0	0	0	0	149
		120107*	Y8	0	9	1	1	1	0
	R9			22992	26632	23423	28799	18722	33340
Belgium	**total**			36915	40633	46629	61086	45962	60716
Bulgaria	R9	130110*	Y8	0	0	0	282	316	592
Croatia	D9	120109*	Y9	0	80	0	0	0	0
Czech Repu	R9	130208*	Y8	0	0	0	1858	179	525
		130205*	Y8	0	0	3352	5497	6987	3691
Czech Repu	**R9**			0	0	3352	7355	7166	4216

Table 27-8 Treatment of waste oils by waste management operations and by MS; Eurostat [env_wastrt], years 2014 and 2016, tonnes and %

2014 tonnes/ %	D1, D5, D12	D1, D5, D12	D10	D10	D2-D4, D6-D7	D2-D4, D6-D7	R1	R1	R2-R11	R2-R11
BE	0	0%	708	2%	0	0%	0	0%	43375	98%
BG	0	0%	0	0%	0	0%	0	0%	11445	100%
CZ	33	1%		0%	0	0%		0%		53%
DK	3008	5%	1840	3%	0	0%	5166	8%	54164	84%
DE		0%		0%	0	0%	28104	3%	985238	96%
EE	0	0%	0	0%	0	0%	210	24%	652	76%
IE	0	0%	0	0%	0	0%	12824	99%	135	1%
EL	0	0%	0	0%	0	0%	625	3%	24015	97%
ES	665	0%	0	0%	0	0%	571	0%	171329	99%
FR	1502	1%	36386	12%	0	0%	66250	22%	191055	65%
HR	0	0%	0	0%	0	0%	6141	99%	56	1%
IT	1273	1%	3037	1%	0	0%	5965	3%	217029	95%
CY	2	0%	0	0%	0	0%	0	0%	7778	100%
LV	0	0%	1	0%	0	0%	113	3%	4202	97%
LT	0	0%	141	11%	0	0%	0	0%	1190	89%
LU	0	0%	0	0%	0	0%	0	0%		0%
HU	58	0%	8995	38%	0	0%	321	1%	14419	61%
MT	0		0		0		0		0	
NL	1036	1%	10444	14%	2470	3%	22908	30%	40120	52%
AT	0	0%		0%	0	0%		0%	2299	13%
PL	0	0%	1117	1%	0	0%	186	0%	139106	99%
PT	0	0%	0	0%	0	0%	93	0%	53157	100%

2014 tonnes/ %	D1, D5, D12	D1, D5, D12	D10	D10	D2-D4, D6-D7	D2-D4, D6-D7	R1	R1	R2-R11	R2-R11
RO	2043	4%	583	1%	0	0%	35062	77%	8141	18%
SI	0	0%	24	2%	0	0%	141	15%	799	83%
SK	616	7%	97	1%	1662	19%	571	6%	5942	67%
FI	11	0%	7693	25%	0	0%	3164	10%	19611	64%
SE	18	0%	3936	10%	0	0%	29630	72%	7621	18%
UK	366	4%	0	0%	0	0%	0	0%	8399	96%
EU-28	10.000	0%	90000	4%	0	0%	230000	10%	2010000	86%

: not available

2016 tonnes/ %	D1, D5, D12	D1, D5, D12	D10	D10	D2-D4, D6-D7	D2-D4, D6-D7	R1	R1	R2-R11	R2-R11
BE	0	0%	341	1%	0	0%	0	0%	54145	99%
BG	0	0%	0	0%	0	0%	452	2%	20052	98%
CZ	:	0%		18%	:	0%		0%		74%
DK	4379	8%	1861	3%	0	0%	3107	5%	47868	84%
DE		0%		0%	0	0%	44802	5%	869445	94%
EE	0	0%	0	0%	0	0%	347	41%	505	59%
IE	0	0%	0	0%	0	0%	14246	100%	0	0%
EL	:	0%	:	0%	:	0%	:	0%	:	0%
ES	2989	2%	0	0%	30	0%	1103	1%	155213	97%
FR	228	0%	27996	9%	0	0%	93917	31%	181437	60%
HR	0	0%	0	0%	0	0%	6560	99%	87	1%
IT	1215	1%	3577	2%	0	0%	2409	1%	217330	97%
CY	2	0%	0	0%	0	0%	0	0%	6638	100%

2016 tonnes / %	D1, D5, D12	D1, D5, D12	D10	D10	D2-D4, D6-D7	D2-D4, D6-D7	R1	R1	R2-R11	R2-R11
LV	0	0%	0	0%	0	0%	70	2%	3918	98%
LT	0	0%	0	0%	0	0%	355	16%	1808	84%
LU	0	0%	0	0%	0	0%	0	0%		0%
HU	115	0%	5261	23%	0	0%	1415	6%	16222	70%
MT	0		2		0		0		0	
NL	105	0%	6965	20%	9988	29%	1662	5%	15319	45%
AT	0	0%		0%	0	0%		0%	2106	8%
PL	0	0%	1730	2%	0	0%	122	0%	105409	98%
PT	0	0%	0	0%	0	0%	4	0%	27436	100%
RO	234	1%	2166	5%	0	0%	18710	43%	22010	51%
SI	0	0%	153	3%	0	0%	3368	72%	1132	24%
SK	289	3%	60	1%	1418	16%	115	1%	6999	79%
FI	6	0%	0	0%	0	0%	1572	3%	44196	97%
SE	0	0%	5860	21%	0	0%	21594	79%	0	0%
UK	240	1%	3146	11%	0	0%	0	0%	24794	88%
EU-28	10.000	0%	80000	4%	10000	0%	240000	11%	1850000	84%

: not available

27.3 Annex III Comparison PRODCOM total and sold production

PRODCOM databases DS-066341 and DS-066342

EU-28 (2017), UNIT ktonnes

Prodcom label	Sold	Total	sold/total
EDC	1 201	3 042	39%
digol	55	79	70%
MIBK	40	60	67%
Acetic acid	592	122	486%
Acetone	1 398	1 576	89%
Acyclic ethers+	2 000	2 057	97%
Acyclic ketones+	28	73	38%
Benzene	6 109	6 919	88%
BTX	2 077	2 354	88%
Butan-1-ol	298	487	61%
Butanols, other	86	93	93%
MEK	177	168	105%
Carbon tetrachloride	23	23	101%
Chloroform	134	121	111%
Cyclanes+	150	147	102%
Cyclohexane	712	726	98%
EtOH, denatured	1 139	-	n.a.
DCM	180	180	100%
Esters of acetic acid, other	737	1 010	73%
Ether-alcohols+	550	624	88%
Ethyl acetate	60	64	94%
Ethylene glycol	1 242	1 211	103%
Methanol	1 500	1 500	100%
m-Xylene and mixed xylene isomers	946	385	246%
Aromatics	3 414	4 608	74%
Cyclic HC, other	869	1 500	58%
o-Xylene	401	479	84%
Propanol (n-), IPA	354	493	72%
Propylene glycol	708	676	105%
p-Xylene	1 045	1 366	77%
Saturated acyclic hydrocarbons	885	1 171	76%
THF, furfural +	18	50	36%
Toluene	1 424	1 300	110%
TRI, PER	123	160	77%
EtOH, undenat.	4 479	-	n.a.

27.4 Annex IV Applications for solvent VOC sales according to ESIG (ESIG 2019, ESIG 2018d)

Application	Comment	Release-to-air-ratio (as VOC) applied by ESIG (2018d)
Agrochemical uses		100%
Blowing agents		100%
De-icing	all areas included	100%
Binder & release agents		100%
Cleaning, industrial	also including leather treatment, electronics, semiconductor	70%
Cleaning, professional / consumer	dry cleaning agents used by professionals (very low release percentage) and the other cleaning agents used by consumers (completely released to atmosphere)	50%
Coatings, industrial	also including adhesives, resins, inks, refining and blending + reprographics; coating of new cars	(10%) 75%
Coatings, professional / consumer	including thinners, paint industry, emulsions and automotive (repair shops) in professional and consumers applications	75%
Functional solvents	solvents used in chemical processes including intermediates, polymerization and extraction; ESIG participants´ internal uses (whether solvent or intermediate) are excluded	10%
Metal working/lubricants	metal working, rolling oils, lubricant uses	0%
Drilling/mining/extraction		0%
Polymer processing	incl.rubber-tyre production, resins, rubber	10%
Road and construction		95%
Use as fuel	use as fuel/combustion; mainly industrial	0.25%
Water treatment		5%
Other consumer uses	household, aerosols, cosmetics	90%
Pharmaceuticals		30%

27.5 Annex V Selected LoW Codes for solvents and other hazardous organic liquids

Table 1: Spent solvents included in WStatR Chapter 01.1 "Spent solvents"

LoW Code	Label	Comment
07 01 03*	organic halogenated solvents, washing liquids and mother liquors	WStatR 01.1 halogenated
07 01 04*	other organic solvents, washing liquids and mother liquors	WStatR 01.1 non-halogenated
07 02 03*	organic halogenated solvents, washing liquids and mother liquors	WStatR 01.1 halogenated
07 02 04*	other organic solvents, washing liquids and mother liquors	WStatR 01.1 non-halogenated
07 03 03*	organic halogenated solvents, washing liquids and mother liquors	WStatR 01.1 halogenated
07 03 04*	other organic solvents, washing liquids and mother liquors	WStatR 01.1 non-halogenated
07 04 03*	organic halogenated solvents, washing liquids and mother liquors	WStatR 01.1 halogenated
07 04 04*	other organic solvents, washing liquids and mother liquors	WStatR 01.1 non-halogenated
07 05 03*	organic halogenated solvents, washing liquids and mother liquors	WStatR 01.1 halogenated
07 05 04*	other organic solvents, washing liquids and mother liquors	WStatR 01.1 non-halogenated
07 06 03*	organic halogenated solvents, washing liquids and mother liquors	WStatR 01.1 halogenated
07 06 04*	other organic solvents, washing liquids and mother liquors	WStatR 01.1 non-halogenated
07 07 03*	organic halogenated solvents, washing liquids and mother liquors	WStatR 01.1 halogenated
07 07 04*	other organic solvents, washing liquids and mother liquors	WStatR 01.1 non-halogenated
14 06 01*	chlorofluorocarbons, HCFC, HFC	WStatR 01.1 halogenated
14 06 02*	other halogenated solvents and solvent mixtures	WStatR 01.1 halogenated
14 06 03*	other solvents and solvent mixtures	WStatR 01.1 non-halogenated
20 01 13*	Solvents	WStatR 01.1 non-halogenated

Table 2: Waste streams containing solvents from paint & varnish, ink, adhesives & sealants

LoW Code	Label	Comment
08 01 11*	waste paint and varnish containing organic solvents or other hazardous substances	WStatR 02.13
08 01 17*	wastes from paint or varnish removal containing organic solvents or other	WStatR 02.13
08 01 21*	waste paint or varnish remover	WStatR 02.14
08 03 12*	waste ink containing hazardous substances	WStatR 02.13
08 04 09*	waste adhesives and sealants containing organic solvents or other hazardous substances	WStatR 02.13
08 01 13*	sludges from paint or varnish containing organic solvents or other hazardous	WStatR 02.13
08 03 14*	ink sludges containing hazardous substances	WStatR 02.13
08 04 11*	adhesive and sealant sludges containing organic solvents or other hazardous	WStatR 02.13
20 01 27*	paint, inks, adhesives and resins containing hazardous substances	WStatR 02.13

Table 3: Waste streams containing solvents from other applications

LoW Code	Label	Comment
03 02 01*	non-halogenated organic wood preservatives	WStatR 02.14
03 02 02*	organochlorinated wood preservatives	WStatR 02.14
04 02 14*	wastes from finishing containing organic solvents (textile & leather)	WStatR 02.14
11 01 13*	degreasing wastes containing hazardous substances	WStatR 01.22
16 01 13*	brake fluids	WStatR 02.14
16 01 14*	antifreeze fluids containing hazardous substances	WStatR 02.14

Table 4: Waste streams of other hazardous organic liquids

LoW Code	Label	Comment
07 01 07*	halogenated still bottoms and reaction residues	WStatR 03.13
07 01 08*	other still bottoms and reaction residues	WStatR 03.13
07 02 07*	halogenated still bottoms and reaction residues	WStatR 03.13
07 02 08*	other still bottoms and reaction residues	WStatR 03.13
07 03 07*	halogenated still bottoms and reaction residues	WStatR 03.13
07 03 08*	other still bottoms and reaction residues	WStatR 03.13
07 04 07*	halogenated still bottoms and reaction residues	WStatR 03.13
07 04 08*	other still bottoms and reaction residues	WStatR 03.13
07 05 07*	halogenated still bottoms and reaction residues	WStatR 03.13
07 05 08*	other still bottoms and reaction residues	WStatR 03.13
07 06 07*	halogenated still bottoms and reaction residues	WStatR 03.13
07 06 08*	other still bottoms and reaction residues	WStatR 03.13
07 07 07*	halogenated still bottoms and reaction residues	WStatR 03.13
07 07 08*	other still bottoms and reaction residues	WStatR 03.13
Only in some case:		
16 03 05*	organic wastes containing hazardous substances (from off-specification batches and	
16 05 06*	laboratory chemicals, consisting of or containing hazard. substances, incl.	WStatR 02.31
16 05 08*	discarded organic chemicals consisting of or containing hazardous substances	WStatR 02.31
16 07 09*	wastes containing other hazardous substances (from transport tank, storage tank and	

27.6 Annex VI Comparison between national reporting (MS survey 2019 / Destatis 2016) and Eurostat reporting (WStatR Category 01.1); Reference Year: 2016

Unit: kt	generation		treatment, total		net trade		D10 (DE: D10+R1)		R1		Recycling (R2-R11)		Other	
MS	national*	Eurostat	national*	Eurostat	national*	WShipR	national*	Eurostat	national*	Eurostat	national*	Eurostat	national *	Eurostat
CZ	11	10	7	7			5	5	0	0	2	2	0	
DE	668	766	679	711		15	501	487	incl. in D10	incl. in D10	178	224		
DK**	34	35	19**	48	10	20	15**	0.2	2**	33	2**	15	0.1**	
PT***	18	10	18***	5	0.4	0.2	0***	0.1	7***	0	7***	5	4***	
EE	0.4	0.4												
HR	1.8	1.8												
LV	0.3	0.6												

* national contribution: MS survey 2019 / for DE: Destatis 2016

** DK treatment given only for nationally generated waste; WShipR and MS survey (2019) indicate relevant import (≈20kt in 2016), MS survey (2019) additionally reports export (≈10kt in 2016), cf. Chapter 22.3.

*** PT treatment given only for nationally generated waste; trade volumes negligible according to MS survey (2019), WShipR

The highest volumes are treated in **Germany** with an equal split between recycling, energy recovery and disposal by incineration. The reported volumes are in reasonable agreement with the data from Destatis (2019). As detailed in Chapter 22.2, some uncertainty with respect to spent solvent volumes used in cement kilns exists.

The data reported for the **Czech Republic** by MS survey (2019) and Eurostat are in good agreement with a tendency towards disposal by incineration. 30% recycling are reported.

In **Denmark** based on Eurostat energy recovery (R1) dominates. However, Danish data on the treatment of their locally produced solvent waste (excluding imports)[235] report that disposal by incineration is by far the major treatment option (76%, MS survey 2019). According to MS survey treated imported waste in DK is most likely reported as R1 treatment and treated domestic waste is often reported as D10 treatment even though it is the same type of waste treated in the same way. In Denmark there are two companies treating hazardous waste by incinerators with energy recovery/without energy recovery and at least two companies treating hazardous waste in co-processing (MS survey 2019). In general, there is no solvent recycling activity in Denmark, for one single LoW entry (pharmaceutical origin) R3 treatment is reported[236] (MS survey 2019). Consequently, the recycling share indicated by Eurostat appears too high. The total treatment of 48kt reported for DK by Eurostat is higher than the treatment reported for nationally generated waste via the MS survey plus the import identified in Chapter 22.3 for Denmark (19kt national waste plus import of 20kt[237]). In all cases the imported volumes treated in Denmark are in the same range as its domestic treatment.

For **Portugal** a total treatment of 5kt in 2016 is reported by Eurostat (100% R2) a picture which is not confirmed by the MS survey. The MS survey indicates a treatment of 18kt which consists of R1 (37%, from one LoW code only), R2 (42%) and some other treatment (21%, in general intermediate treatment before being sent to final destination) (MS survey 2019). If this “other treatment” is substracted from the total value, a national treatment of 14kt remains, roughly equally falling into R1 and R2. R1 is reported for one LoW code only and according to MS survey there is only one incineration plant which is authorised to treat waste produced on-site only (MS survey 2019).[238] There are two hazardous waste incinerators (D10) also authorized for on-site wastes only. One treats Category 01.1 Spent solvents, in negligible volumes.

For **Latvia** 0.3kt of treatment are reported as 100% R2 (Eurostat and MS survey 2019). While this volume equals the local generation reported in the MS survey, the answer also shows that it would involve export and import considering the breakdown by LoW code provided. From the present analysis of trade some export but no import activity is identified (Chapter 22.3). Also for **Estonia** the treatment activity reported is the same based on Eurostat and MS survey (2019). The very low volume is mainly R1 treatment (one LoW code only). The majority of the generated volume would hence have to be exported, but the trade activity identified in Chapter 22.3 does not explain the difference. For **Croatia** very limited recycling activity is reported for 2016 (MS survey

[235] The MS survey asked to only indicate the split of treatment options for the share of the nationally generated waste. While some MS apparently still answered for total treatment (and for some it was not relevant because trade is negligible, e.g. PT), the Danish answer only contained information on locally generated and treated volumes.

[236] Under this LoW code (070504*) in 2016 2kt are reported as R3 which are most likely used as a carbon-additive to a biogas plant according to MS survey (2019). No other recycling is reported for WStatR Cat. 01.1. This opposes to approx. 15kt (R2-R11) indicated by Eurostat.

[237] The imported quantity of approx. 20kt is also confirmed by MS survey (2019).

[238] Also two cement kilns are indicated, however, no waste quantities incinerated in cement kilns are reported (MS survey 2019).

2019) consistent with the data from Eurostat. No other treatment option is indicated. For 2017 the volume going to recycling increased considerably. This goes along with the recent entry of one Croatian company into ESRG (ESRG 2019, see also Chapter 24.3). For **Slovakia** Eurostat reports a treatment of <1kt with a share of > 80% R2 treatment. In contrast, according to MS survey (2019), there are 22kt of spent solvents generated and treated in the country with a split of 57% D10, 9% energy recovery and 34% recycling (both energy recovery and recycling mainly in the chemical industry (MS survey 2019); the LoW codes included in this quantity are not detailed explicitly, but termed "waste (organic solvents)").

27.7 Annex VII CEMBUREAU statement on utilization of waste oil and spent solvents in EU-28 cement industry

“For the year 2017, according to the statistics collected by the Get the Numbers Right (GNR) project 255.000 tonnes waste oil and 695.000 tonnes spent solvents were utilized by the EU-28 cement industry.

The European cement industry is continuously using waste as a resource, thanks to what is called ‘co-processing’. Co-processing is the combination of simultaneous material recycling and energy recovery from waste in a thermal process.

Co-processing of waste in the cement industry is a more efficient waste management solution than landfilling or incineration and leads to the reduction of our dependence on virgin fossil fuels and the decrease of the amount of waste which is landfilled.”

(CEMBUREAU 2019)

27.8 Annex VIII Reported treatment of spent solvents and other hazardous organic liquids for selected MS (MS survey 2019 / Destatis 2016); Reference Year: 2016

1. Spent solvents included in WStatR Chapter 01.1 “Spent solvents”								
kt in 2016	**Generation**	**Treatment (total)**	**D10**	**R1**	**R2**	**R3**	**Other**	**Comment**
CZ	11	7	5	0	2	0	0	"other" = reuse, R11
DE	668	679	501		178	not evaluated	not evaluated	only D10&R1 evaluated; R2 total aggregate value
DK	19	19	15	2	0	2	0	treatment of nationally generated waste; in addition: import 19kt
PT	18	18	0.1	7	7	0	4	treatment of nationally generated waste; imports negligible; "other" mainly intermediate treatment
2. Waste streams containing solvents from paint & varnish, ink, adhesives & sealants								
kt in 2016	**Generation**	**Treatment (total)**	**D10**	**R1**	**R2**	**R3**	**Other**	**Comment**
CZ	26	6	5	0	1	0	0.01	"other" = reuse
DE	186	-	45		see 1. / Cat. 01.1	not evaluated	not evaluated	only D10&R1 evaluated; R2 total aggregate value under Cat. 01.1
DK	15	15	5	10	0	0	0	treatment of nationally generated waste; net import <10%
PT	8	8	0	0	1	0	7	treatment of nationally generated waste; no imports; "other" mainly intermediate treatment
3. Waste streams containing spent solvents from other applications								
kt in 2016	**Generation**	**Treatment (total)**	**D10**	**R1**	**R2**	**R3**	**Other**	**Comment**
CZ	13	1	0.3	0	0.2	0	0.4	"other" = reuse, R11; hardly any degreasing waste treated in CZ
DE	55	-	0.3		see 1. / Cat. 01.1	not evaluated	not evaluated	only D10&R1 evaluated; R2 total aggregate value under Cat. 01.1; hardly any incineration reported
DK	1	1	0.2	0	0	0	0.8	treatment of nationally generated waste; in addition: import 0.4kt; "other"
PT	1	1	0	0	0	0	0.8	treatment of nationally generated waste; no imports; "other" mainly intermediate treatment

4. Waste streams of other hazardous organic liquids (LoW Codes 07 only)								
kt in 2016	**Generation**	**Treatment**	**D10**	**R1**	**R2**	**R3**	**Other**	**Comment**
CZ	15	15	13	1	0	0	1	"other" = reuse
DE	388	-	446		see 1. / Cat. 01.1	not evaluated	not evaluated	only D10&R1 evaluated; R2 total aggregate value under Cat. 01.1
DK	3	3	3	0	0	0	0	treatment of nationally generated waste; in addition: import 2kt
PT	5	5	1	0	0	0	4	treatment of nationally generated waste; no imports; "other" mainly intermediate treatment

27.9 Annex IX Net trade in spent solvents WStatR Cat. 01.1

UNIT: ktonnes	2012	2013	2014	2015	2016
AT	-1	-14	-3	-1	-5
BE	**-25**	**-17**	**-18**	**-17**	**-17**
BG	0	0	0	0	0
HR	-1	-1	-1	-1	-1
CY	0	0	0	0	0
CZ	0	0	0	0	0
DK	**30**	**25**	**17**	**21**	**20**
EE	0	0	0	0	0
FI	-2	-2	-2	-1	-1
FR	**0**	**39**	**73**	**47**	**32**
DE	**30**	**19**	**12**	**5**	**15**
EL	0	0	-1	0	0
HU	0	0	0	0	0
IE	**-24**	**-22**	**-16**	**0**	**-24**
IT	-11	-3	0	-2	-6
LV	0	0	0	0	0
LT	0	0	0	0	0
LU	0	0	0	0	-1
MT	-1	-1	-1	-1	0
NL	**-30**	**-38**	**-34**	**-25**	**-30**
PL	0	0	0	1	2
PT	0	1	1	0	0
RO	0	0	0	0	0
SK	0	0	0	0	0
SI	-1	-2	-4	-5	-4
ES	-4	-6	-2	-5	-3
SE	-3	0	0	0	-1
UK	**11**	**14**	**11**	**20**	**8**
EU-28	**-34**	**-9**	**32**	**36**	**-14**
EU28_sum_export	189	213	192	161	180
EU28_sum_import	156	204	224	197	165
EU28_delta_ex-im	19%	4%	15%	20%	8%

RED: values > 0 = net import > 1kt
GREEN: values < 0 = net export > 1kt

SOURCE: WShipR, for description of the scope of the WShipR evaluation please refer to Chapter 22.3.

For **Spain** a good agreement is found between the export[239] volume reported by the MS survey (all LoW codes included, cf. Annex III) and that identified by the WShipR evaluation: 7kt and 7.4kt, WShipR and MS survey (2019), respectively. Most of this waste was destined to R2 operations (4.5kt), R1 operations (1.5kt) and to D10 operations (1.2kt) (MS survey 2019). Based on this also for Spain the difference between reported domestic generation and treatment cannot be explained by export activity alone.

While for **Portugal** the overall quantities also matched well (0.6kt vs. 0.64kt, WShipR and MS survey (2019), respectively) the attribution to single LoW codes was not consistent in all cases. The major destinations of Portuguese export are ES, DE, BE and FR.

For **Denmark** the imported volume identified in this study was confirmed by the MS survey (2019).[240] For export, however, neither the total volume of the exported waste (all LoW codes included, cf. Annex III) nor the split by category agreed. In particular, for spent solvents a relevant export of nearly 10kt in 2016 was reported which would considerably reduce the net import (approx. 10kt instead of 20kt)[241].

[239] The MS survey originally only targeted exported quantities.

[240] Follow-up communication with the contributing authority.

[241] It has to be noted that the reported export for 2016 was exceptionally high (13kt vs. 1-2kt in other years) (MS survey 2019)

27.10 Annex X Stakeholders for the collection of hazardous waste (MS survey 2019)

MS	Stakeholders involved in hazardous waste collection
BE (Flanders)	Household waste is regulated by the municipalities, industrial waste is regulated by the IHM framework directive for hazardous waste
CZ	Spent solvents and other hazardous organic liquids are collected by waste treatment facilities, which have permit for collection approved by regional authority.
DK	Public owned collection stations/waste collecting companies/treatment plants maintain the collection of hazardous organic waste.
ES	Collection of spent solvents and other hazardous organic liquids is carried out by authorized establishments or undertakings.
HR	Companies which obtain permit for collection are involved in the collection of spent solvents and other hazardous organic liquids. The Waste Management Permit Database contains information on the companies which obtain permit for either collection, recovery or disposal and is publicly available (http://regdoz.azo.hr).
LV	Solvent collection is done by hazardous waste management companies, which have special permits and equipment.
PT	The collection and transport of these waste can be made by producers or stakeholders involved in waste management process, which includes waste treatment operators, waste transporters, dealers and brokers.

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