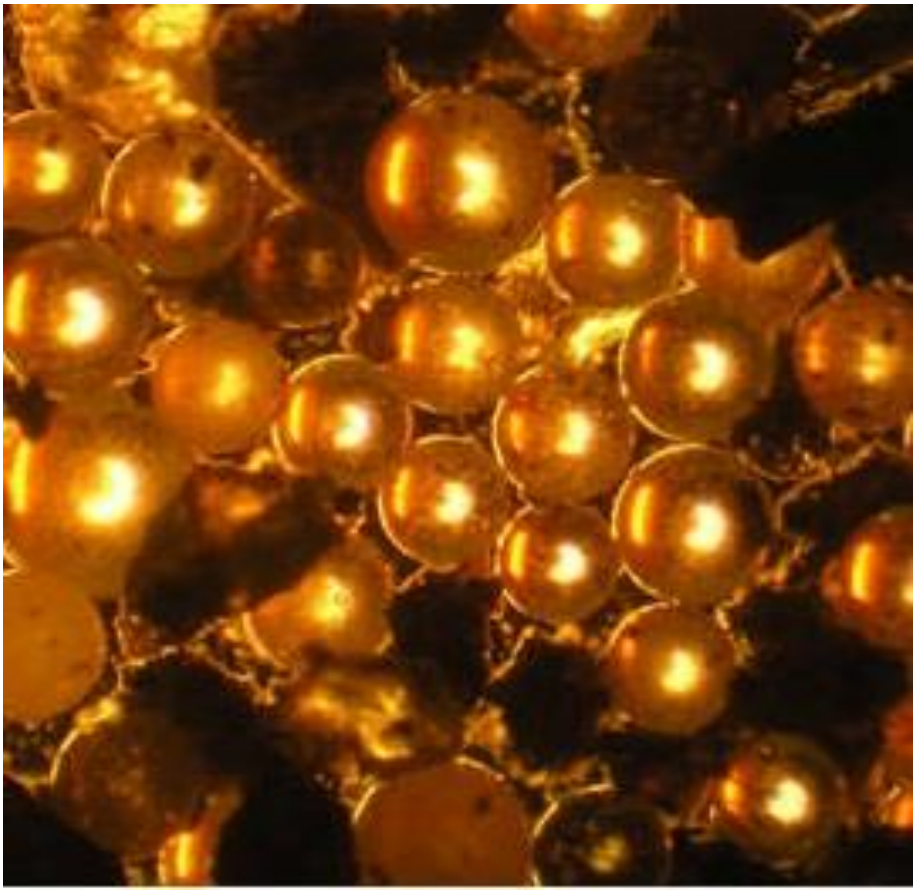

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Primary microplastic-pollution: Measures and reduction potentials in Norway

April 2016

Project report

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Utdrag/ Abstract:

This report describes and assesses both generic and specific measures to reduce microplastic emissions from primary sources. In total the report covers about 50 measures.

An overall national strategy to combat microplastic pollution can consist of different instruments and both generic and specific measures. The report concludes and proposes six specific and four generic measures as the most cost efficient and feasible measures for a national plan to combat microplastic pollution. However, for several reasons further discussions are needed on the composition of specific and generic measures as basis for a good national strategy.

The report is based on the Mepex report on microplastic pollution sources from 2014, updated literature and a close dialogue (partly by workshops) with experts and industry leaders. The assessment is summarized using a rough multicriteria scorecard - a methodology also used by OSPAR.

We use the same definition on microplastic as in 2014, but the need for further discussions on definitions is also raised in this report. We compare the estimates on emissions from the 2014 study with other recent studies. While there are still differences among the studies, all studies are focusing on the same key emission sources.

In this report, we have assessed the measures source by source in different chapters:

- Road traffic, Paint, Textiles, Cosmetics/ Detergents, Pellet loss and Waste/recycling.
- In addition, we use two "other" catch-all categories, one being industrial and offshore uses, and one being additional sources, such as artificial football pitches.
- Last but not least, wastewater and sewage plants are treated in this report as a separate category. This group is also a pathway for other sources and therefore includes of emissions from other sources.

Each chapter assesses possible measures related to these pollution source groups.

Picture front page: Espen Mariussen. Pellet loss in the seabed outside Norwegian plastic manufacturer.

Emneord/Keywords:	Microplastic-pollution, assessment of measures	**Geografi/Geography:**	Norway
Prosjektleder/Project manager:	Peter Sundt	**Kontroller av/Controlled by:**	Frode Syversen

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1 Summary and key recommendations

The report identifies and discuss a range of possible measures to combat the major microplastic pollution sources. Since the Mepex report 2014 "Sources of microplastic pollution to the marine environment" other studies has strengthened knowledge about what are the most significant sources. There are still challenges related to definitions of microplastics, changes here would increase rather than decrease overall emission estimates.

The suggested measures are based on literature and close dialogue with stakeholders within science, NGOs and industry. For some specific emission groups, we have organized work-shops and meetings. We have also used a subcontractor on specific issues with waste-water treatment technologies. Microplastic pollution is an international challenge and thus requires strategies and plans in cooperation within different relevant organizations. Several measures discussed in this report are also based on international dialogue.

An overall national strategy to combat microplastic pollution can consist of different instruments and both generic and specific measures. This report has assessed about fifty potential measures and concludes that in a national plan the most cost efficient and feasible specific sector-wise measures would be:

- Better road cleaning to collect dust from car tyres and road paint
- Dust and spill control during painting work on boats, ships and constructions
- Improved design and production methods of synthetic textiles, as well as introducing lint filters on washing machines
- Follow up voluntary industry commitments to phase out microplastics in cosmetics and raw material (pellets and dust) loss from plastic industry
- Better construction of artificial football pitches to avoid loss of rubber granulate
- Include the obligation to monitor and avoid microplastic emissions in all industry permits

These specific measures would all depend on the following general measures, with the Environmental Agency and Government taking an active leading role:

- Legal clarification that microplastics should be considered an unwanted pollution and hence is regulated through the normal pollution laws. The issue of microplastic has to be put on the agenda in the dialogue between the Environment Agency, County Governors and industry: an issue for inspections, licensing and reporting.
- Competence within the authorities and responsible sectors about best practise in how to avoid emissions through specific measures, e.g. the ones listed in this report.

This measure also embraces better knowledge about sources, possible volumes of emissions and international exchange in general.

- Voluntary commitments are in some cases mentioned as part of the specific measures in the report. Some commitments already exist. We regard the use of voluntary commitments as an easily achievable element for a national action plan, but such commitments need follow-up and enforcement to be effective.
- The issue of microplastics shall be taken into account for future national waste water treatment strategies.

1.1 Sammendrag på norsk. Summary in Norwegian.

Denne rapporten beskriver og evaluerer en rekke mulige tiltak for å bekjempe mikroplastutslipp fra ulike forurensningskilder.

Siden Mepex rapporten i 2014 "Kilder til mikroplast forurensning til det marine miljø" har andre studier styrket vår kunnskap om hva som er de viktigste kildene. Det er fortsatt utfordringer knyttet til definisjoner av mikroplast, men endringer her vil heller øke enn minske de samlede utslippsestimater.

De foreslåtte tiltakene er basert på litteratur og tett dialog med interessenter innen vitenskap, frivillige organisasjoner og næringsliv. For noen spesifikke utslippsgrupper har vi organisert workshops og møter. Vi har også brukt en underleverandør på bestemte tema innenfor avløpsvannbehandling.

Mikroplastforurensning er en internasjonal utfordring og krever samarbeid. Flere tiltak omtalt i denne rapporten er også basert på internasjonal dialog.

En samlet nasjonal strategi for å bekjempe mikroplastforurensning kan bestå av ulike virkemidler og både generiske og spesifikke tiltak. Rapporten beskriver og vurderer om lag 50 mulige tiltak og konkluderer med at følgende tiltak er de mest kostnadseffektive og mest gjennomførbare:

- Bedre vasking av veier for å samle støv fra bildekk og veimaling
- Støv- og utslippskontroll ved maler- og vedlikeholdsarbeid både av båter og andre konstruksjoner
- Bedre design og produksjonsmetoder for syntetiske tekstiler, samt innføre effektive lofiltre på vaskemaskiner
- Følge opp frivillige bransjeinitiativ for å fase ut mikroplast i kosmetikk og unngå unnslipp av granulat fra plastbransjen
- Bedre design og sikring av kunstgress- fotballbaner for å unngå tap av gummigranulat og kunstgress
- Inkludere en forpliktelse om å overvåke og unngå mikroplast utslipp i alle industritillatelser

Disse konkrete spesifikke tiltakene vil avhenge av følgende generelle tiltak, der Miljødirektoratet og andre myndighetsorganer tar en aktiv lederrolle:

- En juridisk avklaring slik at mikroplast klart klassifiseres som en uønsket forurensning og dermed er regulert gjennom forurensningsloven og aktuelle forskrifter. Mikroplast må settes på dagsorden i dialogen mellom Miljødirektoratet, fylkesmennene og næringslivet slik at det inngår i tilsynet, konsesjoner og rapportering.

- Utvikle kunnskapen om mikroplast innenfor myndighetene og ansvarlige sektorer. Dette omfatter utslippskilder, mulige volumer og beste praksis for hvordan man skal unngå utslipp gjennom konkrete tiltak.

- Frivillige forpliktelser er i flere tilfeller nevnt som spesifikke tiltak i rapporten. Dette er basert på det faktum at noen slike allerede eksisterer i noen sektorer. Vi mener frivillige forpliktelser har et betydelig potensiale i en nasjonal strategi for å forebygge mikroplast utslipp. Men det trengs også oppfølging og håndheving av slike frivillige avtaler.

- Som en siste hjørnestein i en nasjonal strategi bør også behandling av avløpsvann i Norge vurderes og veies opp mot ovennvnete tiltak ved utslippskildene. Selv om vi har mange gode renseanlegg, er andelen mikroplast som i dag fanges opp ikke god nok. Dessuten brukes slammet med mikroplast ofte som gjødsel og fører dermed mikroplast tilbake til naturen med fare for å ende i vannsystemene igjen. En nasjonal strategi for avløpsvann bør ta hensyn til mikroplast.

2 Introduction

There is a growing awareness that microplastics, small plastic particles, is a pollution problem that should be given higher concern. Microplastics are emitted both from primary sources, such as everyday plastic products and man-made processes, and from secondary sources, such as natural fragmentation of marine plastic litter. This report is about how to combat the primary microplastic sources. The Norwegian Environment Agency is, on behalf of the Norwegian Government, working to identify and discuss a range of measures that could reduce microplastic emissions into the Norwegian seas. Based on our former study (2014) on emission sources, we were commissioned to produce this new report to describe and assess relevant measures as a next step towards a national plan to combat primary microplastic emissions.

We base this report on the estimates from the former Mepex report "Sources of microplastic pollution to the marine environment" from 2014. However, we discuss and adjust the relative importance of different sources based upon updated knowledge. Key new knowledge includes: the Eunomia report on overall European microplastic emissions[1]; the Danish COWI report[2]; and the German Nova Institute report from 2015[3]. A study in Sweden is currently in progress. Eunomia has developed figure 2-1, to illustrate the sources and the pathways.

[1] Hann,Simon, Eunomia. 5 September 2015, Study to support the development of measures to combat a range of marine litter sources. WP 2: Preliminary scoping exercise of options to achieve a phase-out or ban of microplastics in cosmetic products. Report for DG Environment, European Commission.
[2] Lassen, C. et al. Microplastics- Occurence, effects and sources of releases to the environment in Denmark. Published by The Danish Environmental Protection Agency, 2015
[3] Essel, R. et al.Sources of microplastics relevant to marine protection in Germany.On behalf of the Federal Environment Agency, Germany , 2015

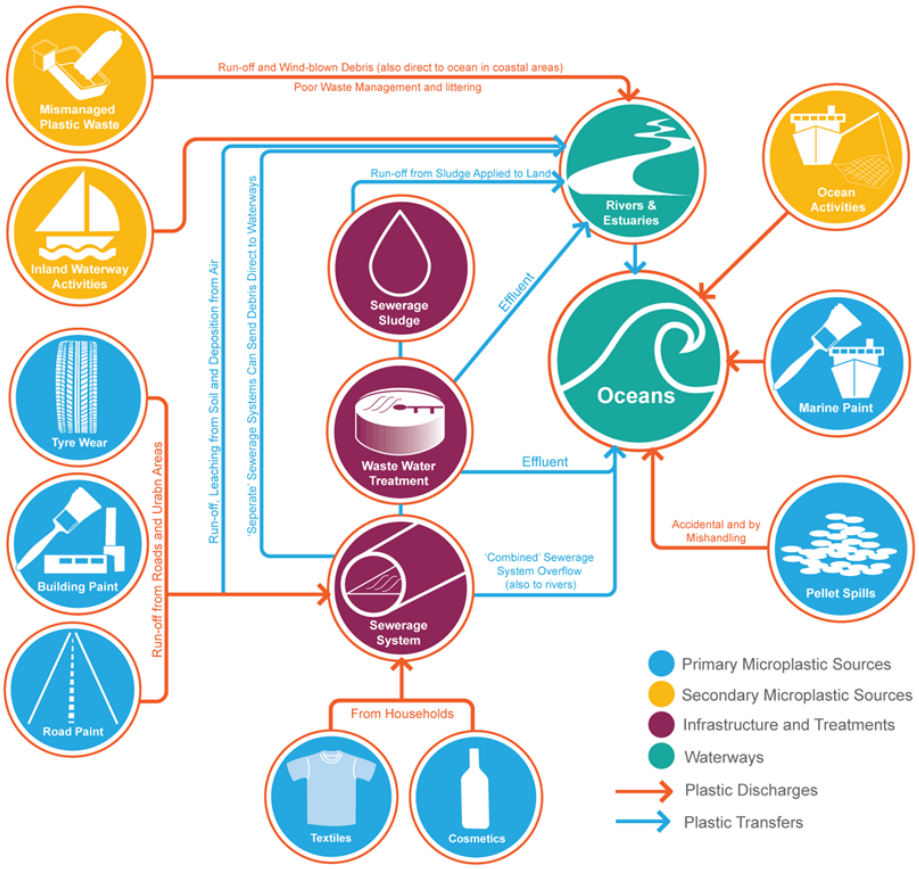


Figure 2-1 Major microplastic sources and pathways to the environment (Eunomia 2015).

The illustration Figure 2.1 underlines the core role of the wastewater and sewage systems, including the run off from sludge applied as fertilizers. It is important to underline that some microplastics are not captured by the waste water system and discharge directly into waterways. The rivers in Northern Europe are important pathways for microplastics to the ocean.

The different sources illustrated in Figure 2-1 also represent the chapters in this Mepex report. However, the illustration does not contain artificial football pitches, an important source in Norway, described in chapter 13 of this report. There might also be other sources, not yet examined.

This report comprises the key sources of microplastic emissions we know of today. Cosmetics and detergents are included in chapter 9, even though these sources are small compared to other sources. However, it seems that politicians, media, the EU Commission and OSPAR have started their work on cosmetics. This underlines the need for upfront estimates of all sources and not just focusing on the sources discussed in media.

Microplastic emission estimates are different volumes if you view them at the upstream source, or as discharges downstream to the sea. In our former report and also in this report focussing on measures we keep most of our focus upstream at the sources.

The following table 2-1 compares the estimated gross microplastic pollution (at source) in grams per capita, comparing Norway, Germany, Denmark and EU estimates. The figures are based Mepex 2014, NOVA 2015, Cowi 2015, Eunomia 2015. The estimates, measured at source, range from 171 g/ capita to almost 4 kg/ capita, underlining the need for further studies. Details are discussed further for each source of this report.

Table 2-1 Comparison of estimated microplastic pollution in g per capita, different countries

Population	5165k	80688k		5699k		508000k	
Country Estimates	Norway 2014	Germany 2015		Denmark 2015		EU	
	Buest guess	Low	High	Low	High	Low	High
Personal care & cosmetics	8		6	2	5	8	
Pellets (raw material)	87	260	2603	1	10	112	1122
Paints	238			28	228	55	
Tyres	871	744	1376	737	1158	63	
Textiles	136			35	175	53	
Road markings	62			19	121		
Others	210		2	143	742		
Totals	1612		3992	965	2439	171	1302

Norway plays an active role within the Oslo and Paris Conventions for protecting the marine environment (OSPAR) and their marine litter regional action plan from 2014[4]. Action 46 (evaluate all products and processes) and 47 (voluntary agreement on cosmetics) in this action plan are regarded as the basis for OSPAR work on microplastics. Other actions are also relevant, for example 42 (best available technology by sewage and storm water) and 52 (pellet losses).

On a European level, the EU Commission is working on both marine littering and microplastics. The UK environmental consultancy, Eunomia, has recently quantified the cosmetics derived microplastic emissions, and mapped this to industry commitments. The draft report, presented in Cologne on 23 November[5], also discusses other microplastic emissions.

[4] The Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention') was open for signature at the Ministerial Meeting of the Oslo and Paris Commissions in Paris on 22 September 1992. It was adopted together with a Final Declaration and an Action Plan

[5] Hann, Simon, Eunomia, Scale of microplastic emissions in Europe- Insights of a study for the European Commission. Presentation at the Nova- Institute Microplastics conference in Cologne, 23-24 November 2015

Norway aims at presenting a national strategy against both marine littering in general and microplastic sources in particular within 2016.

3 Aim and scope of study

The aim of this report is to list and evaluate potential specific and general measures against microplastic pollution. Measures related to the different sources are assessed, source by source, in chapter 6-14. As far as possible we estimate a net reduction potential for each measure, and describe and evaluate each measure systematically.

The evaluation of measures should take cost/benefit and feasibility into consideration. The Dutch consultancy Ecorys has presented a multi-criteria analysis, a model for evaluation, discussed within OSPAR in December 2015. Mepex has adjusted this assessment model, see chapter 4.6, and used their model in this study. We underline that this method is very rough and that further research may be needed for particular measures chosen.

Only measures found most important, cost-efficient and feasible are included in the key recommendations. A summary evaluation table including all measures and their evaluation scores are found in Appendix 1- chapter 16.

The different measures can be overlapping, dependent of each other, or in synergy with each other. In some cases, generic measures can boost or replace specific measures. A strategy has to choose or sometimes combine different kinds of measures. The final design of such a national strategy is left to the Environment Agency and politicians, with this report contributing information and perspectives.

4 Methods

4.1 Definitions

The definitions of "microplastics" used in this report are the same as in the previous report "Sources of microplastic pollution to the environment" and summarized in table 4-1 below.

Table 4-1 The microplastic definition

General characteristics	Comments
Solid phase material	Solid particulates, not fluid/ liquid. Includes particles in suspensions, but those harder than particles in waxes. Some polymers are not solid.
Insoluble in water	Lack of knowledge on degradation in water, so "insoluble" is to be understood as a relative term.
Synthetic	Often polymers can be regarded as "synthetic", but not always. Better wording might be "man- made" polymers
Slowly degradable	Some plastics claim they are "biodegradable". Other plastics degrade slowly, for example in the sun.
Made from plastics	Such particles, also other "particles made from polymers" should be included, as long as the particles are solid.
Small size < 5mm	Includes very small particles, even at the nano-scale. Particles can have all kinds of shape.

In the literature, there are still discussions on if the definition of microplastics should be extended, e.g. to include softer particles. See appendix 2, chapter 17 for more on this.

4.2 Literature

Literature we list as footnotes in the text of this report.

4.3 Stakeholder involvement (including authorities)

We base this report on extensive dialogue with stakeholders. We list these references in chapter 15.2. In addition to direct contact by phone and mail, we also organized some workshops, meetings and telephone meetings as part of the process. We refer to these stakeholder meetings, workshops and telephone conferences in the following chapters.

In addition, Mepex has been involved in three key meetings/conferences, also as important sources of information for this report:

- Stakeholder meeting at the EU Commission on 20 October, 2015. At this workshop, microplastics was on the agenda, with specific discussion of options to achieve a phase-out or ban of microplastics in cosmetic products. The discussions were based

on presentations and reports from Eunomia.[6] Key stakeholders were present, such as Cosmetics Europe, Plastics Europe, several NGOs, DG Environment and others, including the Norwegian Environment Agency and Mepex. (see chapter 7)

- NOVA Institute conference in Cologne 23-24 November, 2015. The conference "Microplastics in the environment - sources, impacts and solutions" also focused on different biodegradable plastics and degradability in seawater.
- OSPAR meeting in Rotterdam 9-10 December, 2015. This seminar focused on measures and instruments to stop microplastics entering the marine environment.

4.4 Model: Groups of pollution sources

In this report, we have grouped the different sources of microplastic pollution in different chapters:

- Road traffic, Paint, Textiles, Cosmetics/ Detergents, Pellet loss and Waste/recycling.
- In addition, we use two "other" catch-all categories, one being industrial and offshore uses, and one being additional sources, such as artificial football pitches.
- Last but not least, wastewater and sewage plants are treated in this report as a separate category. This group is also a pathway for other sources, and therefore includes of emissions from other sources.

Each chapter assesses possible measures related to these source groups.

4.5 Potentials for reductions

In each chapter, we will describe and discuss reduction potentials for the most relevant sources. The *gross* potential equals the total emissions, while the *net* potentials refer to realistic reductions related to the proposed measure, or group of measures.

Combined, synergetic or negative effects of different measures on each other are mentioned where possible, but not elaborated in detail. This needs more work, e.g. in flow charts.

4.6 Evaluation criteria for relevant measures

According to the project requirements from the Norwegian Environment Agency, this project shall evaluate proposed measures according to the following criteria with brief explanations:

[6] Hann, Simon, Eunomia. 5 September 2015, Study to support the development of measures to combat a range of marine litter sources. WP 2: Preliminary scoping exercise of options to achieve a phase-out or ban of microplastics in cosmetic products. Report for DG Environment, European Commission.

Cost /Benefit

- Benefits relates to the environmental gain, dependent on the reduced volumes and types of the microplastic pollution.
- Cost/ benefit analyses can refer to total costs for society. In this report, 'costs' often refers to costs impacting defined stakeholders related to only one specific action. Costs thus relates to a given measure, for example costs related to replacing the material used, changing processes, and/or removing emissions by filters or other technologies.

Feasibility

- Evaluation of any barriers, for example technical and legal aspects that can reduce the chance of success of the proposed measure within a given timeframe.
- Evaluation of possible instruments that can remove or reduce these barriers in due time in order to make the measures more feasible.

This report contains almost 50 generic and specific measures. Within the limits of this project it is not possible to calculate costs and potentials for most measures. We have thus searched for a simplified methodology in order to evaluate and compare different measures.

The required abovementioned evaluation criteria are included in our evaluation. We use a scoring scheme, proposed by Ecorys, to evaluate all proposed measures in this report. This scheme harmonizes well with the OSPAR process as basis for international dialogue. This scoring card system consists of three major criteria: [7]

- Emission reduction per measure
- Cost effectiveness (cost per measure per tonne)
- Viability (support for a measure and technical and regulatory feasibility)

Ecorys proposes to weight these three criteria equally, 1/3 each for giving a total score of each proposed measure. We have simplified their model even further, applying a 3-point score for all criteria. The criteria Feasibility is split into Available techniques and Existing Initiatives. In this way, according to the equal weighting model, possible score for the two sub-criteria is 0,5-1,5 points. Our methodology is described further in the table 4-2.

[7] ECORYS, Microplastics, Draft discussion paper for the Ministry of Infrastructure and the Environment, Rotterdam, 26 October 2015.

Table 4-2 Scoring criteria for evaluating different measures against microplastic pollution

Emission reduction	Cost- Effective	Feasibility		Total score
	Cost per tonne	Available Techniques	Existing initiatives	Sum
Score 1-3	Score 1-3	Score 0,5-1,5	Score 0,5-1,5	Score 3-9
1 =low emission reduction / difficult to see gains	**1** = high cost	**0.5** = technique not available	**0.5** = no regulation or initiative exists	3 -5 = measure not recommended without further justification
2 = moderate emission reduction	**2** = moderate cost	**1** =Technique in development	**1** = existing regulation can be transformed	
3 = substantial emission reductions in volume	**3** = low costs	**1.5** = Techniques currently available	**1.5** = existing regulations or initiatives	**6-9 Recommended measure**

This methodology is a simple tool for a first rough evaluation of single measures. As a rule of thumb, we recommend measures that obtain a score of 6 points or higher. Since measures may be linked together, with one measure dependent on another, different measures can strengthen or conflict with one another, we thus suggest further assessment of combined measures and instruments. In this way, measures with lower scores than 6 can also be relevant.

5 Assessment of generic measures

Photo: volunteers clean up marine litter and find microplastics at beaches in Norway. Clean up is costly and for microplastics virtually impossible when it is already in the sea.

5.1 Conclusions and summary

Generic measures can be applied across all sectors and target several or even all primary microplastic pollution sources and thus the total gross potential of emissions.

These generic measures are often needed to support specific actions within each sector, described in the following chapters 6-14.

In general, we often consider generic measures like competence as basic investments for other measures. Such measures we thus give a high score in the evaluation.

We conclude that a national plan to combat microplastic pollution, legal clarification, competence, further knowledge about sources, voluntary commitments and R&D are the most important measures. However, the evaluation is rough, based on our own judgements/ best knowledge. In addition, other measures obtain almost the same scores. We give the lowest score (possible) to a promotion of biodegradable alternatives: We just do not know enough about biodegradation of “biodegradable plastics” in the ocean. Instead, more R&D is needed, inclusive of R&D on substitution alternatives and their impacts.

Measures are evaluated in this report one by one in order to simplify the assessments and the presentation. However, for further discussion on measures, authorities should also take a good mix of measures (push and pull, carrot and stick) into consideration. Such a “mix” relates to both generic and specific measures.

Further details on the evaluation we describe in the tables for each measure in chapter 5.3.

At the OSPAR meeting in Rotterdam 9-10 December 2015, the following generic instruments obtained the most votes by the participants:

- Stimulate innovation, including changes in product design (71%)
- Economic instruments, incl. changes in legislation (46%)

- Public authorities serve as example by public procurement (42%)
- Improve sewage and storm water collection and treatment (40%)
- Restrict use of primary microplastics by legal instruments (34%)
- Encourage best practice and education of professionals (32%)
- Ecolabelling (24%)
- Restrict use of primary microplastics by voluntary instruments (15%)

These proposals were discussed further at the Rotterdam meeting and will be followed up within OSPAR. All these suggestions are, more or less, integrated into the Mepex proposals below. Innovation is for example, integrated in voluntary commitments, R&D and in the specific measures proposed in this report.

Table 5-1 Evaluation scores for generic measures

No	Evaluation of measures - microplastic pollution from: Proposed Measure	Emission reduction	Cost Effective	Feasibility		Total score
			Cost per tonne	Available Techniques	Existing initiatives	Sum
		Score 1-3	Score 1-3	Score 0,5-1,5	Score 0,5-1,5	Score 3-9
5.1	Competence, knowledge and best practice	3	3	1	1	8
5.2	Voluntary commitments	2	3	1	1	7
5.3	Legislative clarifications	3	3	1.5	1	8.5
5.4	Restrict use of microplastics	1	2	1	1	5
5.5	Monitoring rivers and coast	2	2	1	1	6
5.6	Clean ups	1	1	1.5	1	4.5
5.7	Flood preparedness	2	2	1	1.5	6.5
5.8	Ecolabel and Public procurement	1	2	1	1	5
5.9	Biodegradable substitutions and standards	1	1	*1*	1	4
5.10	R&D on microplastics	3	2	1	1	7
5.11	National action plan	3	3	1.5	1.5	9
5.12	Develop further knowledge on sources	3	2	1	1.5	7.5

5.2 Gross reduction potentials

In this chapter on generic measures, we base the analyses and assessments on the total primary microplastic pollution presented and discussed in the chapters 4.4 and 4.5. In general, generic measures cover all sources and we might regard some of them as basic investments in an overall microplastic combat strategy. However, in practice, generic sources might be more relevant more to some specific sources and less to others.

5.3 Description and assessment of measures

Generic measures comprise several sources. In this report we regard measures related to waste water treatment as specific measures, even though these measures might comprise several sources (see chapter 14).

In some cases, we have specified some of the listed generic measures below as part of the specific measures in the following chapters. For example, we have elaborated on the generic measure “Voluntary commitments and Extended Producer Responsibility, EPR” in the chapter of pellet losses.

The following subchapters comprise a brief prescription of 12 generic measures.

5.3.1 Measure 5.1. Competence

Criteria	Comments
Background	Despite some media attention, the issue of microplastics is not well known in society and in business. The wording “Microplastics” can also be regarded as misleading. More information and awareness is thus needed. Awareness and competence are crucial for all other measures.
Objective	• Develop competence, awareness, knowledge and best practice, among professionals, both within authorities and industry. • This includes the Norwegian Environment Agency, County governors, municipalities and even some other Agencies, for example The Norwegian Public Roads Administration. • Furthermore, a link is required between microplastic work and hazardous substances activities. • Last, but not least, to increase competence thorough international cooperation.
Description	Internal training within and between Authorities. Information to stakeholders. Promote dissemination of knowledge within industry and society in general, for example at seminars and by NGO activities. Develop competence by participating in key international initiatives, such as OSPAR.

Possible incentives	Promote dissemination and training.
Reduction potential	Basic measure related to all emissions.
Cost estimates	Moderate. Synergies can be obtained by including this topic with education related to hazardous waste, marine littering and similar topics and dialogue related to relevant industries.
Feasibility	Resources, budgets and available personnel can be barriers in the short run. An overall combat plan with budgets can facilitate this measure.
Link to other measures	5.2 Voluntary commitments, 5.10 R&D

5.3.2 Measure 5.2. Voluntary commitments and EPR

Criteria	Comments
Background	Many companies and business sectors are used to making their own commitments, sometimes as part of EPR (extended producer responsibility) and voluntary agreements. As industrial companies have the best knowledge about their own products (often secret or sensitive information), processes and emissions, these commitments have been proven to be an efficient and innovative way to combat different environmental problems. In relation to microplastics, some industries have already made voluntary commitments, for example within cosmetics and pellet manufacturers.
Objective	Enhance and support voluntary commitments (like pellet losses, cosmetics), EPR and innovation, including substitution and education/ guidance of customers/ consumers (all products/ processes, incl. paint) as part of an overall action plan. Formalize the commitments and follow up.
Description	Stimulate industry to make such commitments or invite them to make voluntary agreements. Use existing voluntary commitments as basis for an overall action plan. Develop the commitments according to the needs, formalize and follow up.
Possible incentives	PR and marketing for industry and if there was some accreditation process (NGO or Government) involving microplastics (similar for example to

	organic certification) this could also be a major incentive for targeted marketing. A voluntary commitment might be regarded as a win- win and an incentive by itself, compared to legislations, bans and taxes etc.
Reduction potential	Commitments are often related to defined value chains.
Cost estimates	Low- moderate
Feasibility	Good experience and examples so far. Might require new thinking from Authorities and formalization. Competition laws might be an obstacle, example cosmetics. Organizations cannot oblige industry to be a member nor to instruct them.
Link to other measures	5.1 Competence

5.3.3 Measure 5.3. Legal clarification

Criteria	Comments
Background	Legislation is regarded as weak and unclear.
Objective	Obtain a basis for better understanding, attention, dialogue, inspections and reporting from industry to authorities, inclusive of information about both use and discharges to the public (as part of "right to know").
Description	Clarify microplastics within legislative frameworks.
Possible incentives	Give industry and regulators unambiguous definitions and targets.
Reduction potential	Relates to all sources
Cost estimates	Low- moderate
Feasibility	No new legislation needed, just to clarify existing legislation and communication. (incl. Pollution Control Act, § 51).
Link to other measures	5.1 Competence, 5.2 Voluntary commitments

5.3.4 Measure 5.4. Restrict the use of microplastics

Criteria	Comments
Background	Some countries restrict the use of microplastics in some products and processes. In this way, industry is forced to find substitutes and alternative processes.
Objective	Limit the use of microplastics in products.
Description	Restrict or ban the use of microplastics in products.
Possible incentives	Same clear rules for all companies, nationally and even internationally.
Reduction potential	Relates to a limited number of sources, e.g. where microbeads/ polymer particles are used in products, such as cosmetics, detergents, paints and as fillings in artificial football pitches.
Cost estimates	Low- moderate.
Feasibility	Other countries plan for this. Lack of alternatives and costs might be obstacles.
Link to other measures	5.9 Promote biodegradable materials, 9.3 Specific ban on microbeads in cosmetics

5.3.5 Measure 5.5. Monitoring rivers and coast

Criteria	Comments
Background	Monitoring rivers is a basis for understanding the extent of pollution and thus an important tool for combatting microplastic pollution. In Europe, there are some programs and models for monitoring rivers and coast, like for the Rhine and Danube rivers.
Objective	Monitoring rivers and coast, especially at hot spots, (both by NGOs and authorities) incl. measurement related to policies and measures based on indicators. Develop equipment and methodology for such monitoring.
Description	Learn from other countries, for example Austria monitoring the Danube river, measuring marine littering and microplastics both in and out of the

	country. Learn from others and develop monitoring systems for microplastics in the water column and in sediments.
Possible incentives	As basis for follow up on other measures, for example related to waste water treatment plants and pellet losses from industrial plants. Win- win for combatting microplastics, waste- water treatment plants monitoring plans and research/ competence in Norway.
Reduction potential	Relates to several sources, locally and regionally.
Cost estimates	Moderate.
Feasibility	Good examples from Germany and Austria. Also some NGO experience. A key element of combat plans at hot spots.
Link to other measures	5.6 Clean ups

5.3.6 Measure 5.6. Clean ups

Criteria	Comments
Background	Based on experience from other micropollutants, it is sometimes necessary to clean up “old sins”, e.g. hot spots of polluted soil or seabed, to avoid further resuspension and leakage into the wider environment. Well- designed measures could largely reduce resuspension of microplastics from normal harbour activities, runoff, storm events and dredging.
Objective	The aim of this measure would be to focus soil and sediment clean up on microplastic hotspots.
Description	A huge programme is already in place to clean up contaminated soils and sediments at many sites around Norway. Microplastics should be included in the parameters and goals for this programme.
Possible incentives	Co-funding from the Government, like for micropollutants. Costly clean ups would not likely be done voluntarily, but would need a formal decision from pollution authorities.
Reduction potential	The standing stock of microplastics in soils and sediments from former pollution could be substantial. Annual resuspension (a secondary source of microplastics) could be substantial. Relevant areas are hot spots outside plastic and paint factories, near artificial soccer turfs, shipyards and

	boatyards, accumulation zones outside rivers and in harbours.
Cost	High. Some experience from coastal clean- up programme.
Feasibility	Like for other soil and sediment clean up
Link to other measures	5.7 Flood preparedness. 5.1 Voluntary commitments.

5.3.7 Measure 5.7. Flood preparedness

Criteria	Comments
Background	Due to climate change, Norway prepares for extreme weather situations and flooding. In general, flood preparedness can minimize the risk of some kinds of microplastics discharges.
Objective	Minimize the risk of microplastics discharges due to flooding.
Description	Prevent emissions and losses by policies, plans and actions to minimize flood damages. Includes both marine littering in general and the issue of microplastics.
Possible incentives	Issue to be included in general flood preparedness plans with extra resources and knowledge.
Reduction potential	Several sources.
Cost estimates	Moderate. Possible to obtain synergies with general flood preparedness planning and activities.
Feasibility	Both OSPAR and HELCOM list similar measures. Coordinate with national flood preparedness and national marine littering plan.
Link to other measures	5.2 Voluntary commitments (especially related to pellet losses), clean-ups, specific measures related to waste water treatment and football pitches.

5.3.8 Measure 5.8. Promote use of Ecolabel and public procurement

Criteria	Comments
Background	Ecolabel is already working on the issue of microplastics (cosmetics) and the Norwegian Ecolabel organization has good competence in this field.

	Public procurement has potentials, one example is Gothenburg.
Objective	Increase awareness, competence and reduce the risk of emissions by Ecolabel activities. Include this issue as part of public procurement and take the role as a frontrunner.
Description	Invite Ecolabel as a key partner in a national combat plan. Include the issue also in public procurement.
Possible incentives	Strengthening the Ecolabel and promoting the issue by Ecolabel in order to make a difference in public procurement.
Reduction potential	Several sources are relevant.
Cost estimates	Low
Feasibility	Use existing agencies as partners, Ecolabel in Norway.
Link to other measures	5.2 Voluntary commitments

5.3.9 Measure 5.9. Promote biodegradable substitutions and standards

Criteria	Comments
Background	The Mepex 2014 report on pollution sources also discussed biodegradable alternatives. The report concluded that we still need more knowledge about biodegradability in the ocean, including at different conditions and places in the water and the sediments. So far, there are almost no safe alternatives available. In the 2014 report, Mepex did not regard biodegradable solutions and standards as a mature alternative and a solution on the microplastic challenges. The measure is still not recommended, but is added to this list of measures as many players in the market are eager to promote such a measure and that this measure is discussed, for example at the Cologne conference in November 2015. The polymer types PHA, PESX, PPSX, PBSX seem to be biodegradable also in the ocean. However, the global production is still very low. Since 1995 certifications have been introduced for industrial composting, home composting, soil, fresh water. Now, some organizations are eager to proceed to the marine sector.
Objective	Replace non-degradable plastics by alternatives that degrade in the ocean.

Description	Alternatives: Promote practical examples and key products where degradable solutions are available, such as Q-tips, products that are not meant to be recycled. Ban on non-degradable plastics Promote biodegradable plastic products by public procurement and economic support. Promote new standards, based on similar standards as for compostable plastics etc.
Possible incentives	PR for some new solutions, for example for Q-tips and other typical marine littering items.
Reduction potential	Limited number of products relevant.
Cost estimates	Moderate.
Feasibility	Certification agencies available, experience from other standards. The American ASTM standard is withdrawn, no standards on biodegradation in the ocean available and lack of knowledge. Challenging to assess the fate of biodegradable materials in different marine environments.
Link to other measures	5.10. R&D related to fate of microplastics in the ocean, also for different kinds of biodegradables. Follow the international debate and research in this field.

5.3.10 Measure 5.10. Research and development, R&D

Criteria	Comments
Background	We need more R & D as the basis for further policy development and to address the knowledge gaps we described in the former Mepex report. The list of gaps and proposals include both specific areas and generic issues. The generic gaps include discussions on definitions (incl. waxes/ lubricants), the nano- issues, studies and characterization of particle findings, comparing particles and weight for mass flow studies, hazardousness, fate in the environment.
Objective	Increase knowledge about microplastics.

Description	R&D on specific areas as basis for better policies, safe substitution alternatives and technologies to reduce other emissions.
Possible incentives	Financing of R&D, incl. international cooperation and financing
Reduction potential	All sources.
Cost estimates	Moderate- High.
Feasibility	Several R&D institutions in Norway with relevant competence and project proposals. OSPAR plans and joint financing.
Link to other measures	5.1 Competence, incl. International cooperation and coordination for synergies, OSPAR, Nordic, UNEP etc.

5.3.11 Measure 5.11. National (or Regional) action plan

Criteria	Comments
Background	Norway is about to develop a national strategy to reduce marine littering. OSPAR has already developed a regional action plan on marine littering, including microplastics. Norway has taken several initiatives on microplastics, but still needs a national plan on microplastics.
Objective	Develop a dynamic national action plan with defined ambitions and relevant measures.
Description	A national plan with prioritized actions in order to combat microplastic pollution.
Possible incentives	Provide a model example for others to follow (OSPAR and others). Obtain overall cost efficiency for Authorities. Obtain attention for microplastic issue and as basis for other measures.
Reduction potential	All sources.
Cost estimates	Low to moderate.
Feasibility	In progress, based on several reports, inclusive Mepex reports.

Link to other measures	All prioritized measures in this report.

5.3.12 Measure 5.12. Studies on pollution sources

Criteria	Comments
Background	For Norway, Mepex in 2014 made some first rough estimates on microplastic emissions from Norwegian primary pollution sources. The results are more or less in harmony with Danish, German and other international report, but still all estimates are very rough. See chapter 4.5. Furthermore, these estimates are so far not linked directly to findings in the ocean. As basis for further measures and instruments, better data are needed, also for any business commitments. In addition, monitoring of the development is required as part of a follow up of the overall national plan and specific measures, incl. voluntary commitments.
Objective	Develop better data on microplastic pollution sources and pathways. Monitor the development from key sources and at hot spots.
Description	New studies on microplastic emissions from key pollution sources. Develop a monitoring plan and monitor key sources and pathways, link studies on sources with studies from the ocean.
Possible incentives	Further projects comprise more dialogue with industry and thus more awareness, competence and commitment. Also basis for more international cooperation. Better data is also a prerequisite for business attention, motivation and action.
Reduction potential	All sources, but possible to focus on big five.
Cost estimates	Moderate.
Feasibility	Based on the first estimates from Mepex in Norway and similar studies from other countries, further studies can be done.
Link to other measures	5.1 Competences, 5.2 Commitments, 5.5 Monitoring rivers and coats, 5.8 Research and development, 5.9 National plan.

6 Assessment of reduction potentials and measures for road traffic

Photo: synthetic rubber dust from car tyres and plastic dust from road paint is the largest source of microplastics in Norway.

6.1 Conclusions and summary

Tyres represent the largest primary source for microplastics in Norway. Recent studies from other countries, including Denmark conclude the same.

Locally in city areas, reduced road traffic would give huge reductions in emissions at moderate cost, but for the country overall, the effect in tonnes would be moderate to small. Changing the road structure to better trap microplastic would be very costly, but possible in new projects and when resurfacing. Better street cleaning is expected to have a high reduction potential, and at a moderate extra cost. In addition, low emission tyres should be added as an additional criteria for quality tyre standards, and in this way promote more research and development and demand in the market.

Table 6-1 Evaluation scores for measures against road traffic related microplastics

No	Evaluation of measures - microplastic pollution from: Road Traffic Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
		Tonnes Reduction	Score 1-3	Cost per tonne Score 1-3	Available Techniques Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
6.1	Reduce road traffic (ref 2016)	750	2	2	1.5	1	6.5

6.2	Low emission tyres		1	2	0.5	0.5	4
6.3	Eco driving	500					
6.4	Improve road surface and sewers		1	1	1	0.5	3.5
6.5	Road cleaning	750	3	2	1.5	1.5	8
TOTAL REDUCTION POTENTIAL		2000	**Out of a total estimated Norwegian discharges at source of about 8.400 tonnes of microplastics (2014)**				

The existing and possible measures to combat microplastics from road dust would also have effect against other polluting components and the well- known adverse effects of road dust. The costs of this measure would hence not have to be covered in full over a microplastic action plan, but would be covered mostly by e.g. climate and urban air quality action plans.

6.2 Gross reduction potentials

6.2.1 Updated summary of gross discharge potentials from road traffic

Mepex (2014) estimated the annual loss of synthetic rubber polymer particles from tyre wear to be 4.500 tonnes with an additional 320 tonnes of plastic particles from road paint. These are gross estimates at-source, based on annual sale volumes for tyres and emission factors. Another line of calculation used is by using vehicle km multiplied by emission per km. However, the number of vehicle km for larger vehicles used in the 2014 report does not include all large vehicles. By also including buses, dumpers and lighter cargo vehicles, a more correct total polymer emissions estimate would increase by about 500 tonnes to a total of 5.000 tonnes. The total particle emissions would be much larger if also including other constituents rather than only the polymer part of the tyre and paint matrix. Counted as whole tyre particles the actual traffic dust weight created by year is about double the polymer only estimate: 10.000 tonnes. A large part of the particles is very small, and would not be trapped in any existing road runoff systems from city surfaces, but to some extent handled by the natural filtering capacity of roadside soils in the countryside. Road dust sediments staying on the road will gradually be grinded, weathered and disintegrate into ever smaller particles.

Three other more recent reports from Denmark, Germany and EU also discusses microplastic pollution from car tyres and road paint.[8] They point out that for road paints some of the annual consumption never gets abraded to particles through traffic, because it is either removed together with asphalt when renovating roads, or used on roads with low weathering and abrasion and therefore lasts several years. Our emission factor of 100% of annual consumption was obviously a worst-case estimate. The Danish report estimated an emission factor of 23-43 % for road paints. In Norway with use of studded tyres and heavy

[8] Simon Hann, Eunomia. 5 September 2015, Study to support the development of measures to combat a range of marine litter sources. WP 2: Preliminary scoping exercise of options to achieve a phase-out or ban of microplastics in cosmetic products. Report for DG Environment, European Commission.

snow removal equipment during winter, the emission factor would be higher and annual emissions probably several hundred tonnes. The exact volume is uncertain.

For particle emission from the use of car tyres there is little discrepancy between Mepex (2014) and other European estimates. Thus it is regarded as reliable that tyres are the largest single source of microplastics to the environment with several thousand tonnes of polymer particles discharged in Norway annually. The Danish report has pointed out that abrasion of other traffic related plastic and rubber surfaces such as shoe soles and bikes would add to the total amount of microplastics in road dust, though in much smaller quantities.

6.3 Description and selection of measures

This chapter lists possible measures to reduce microplastic creation and runoff from streets, while downstream solutions like better treatment of road runoff is covered in chapter 14.

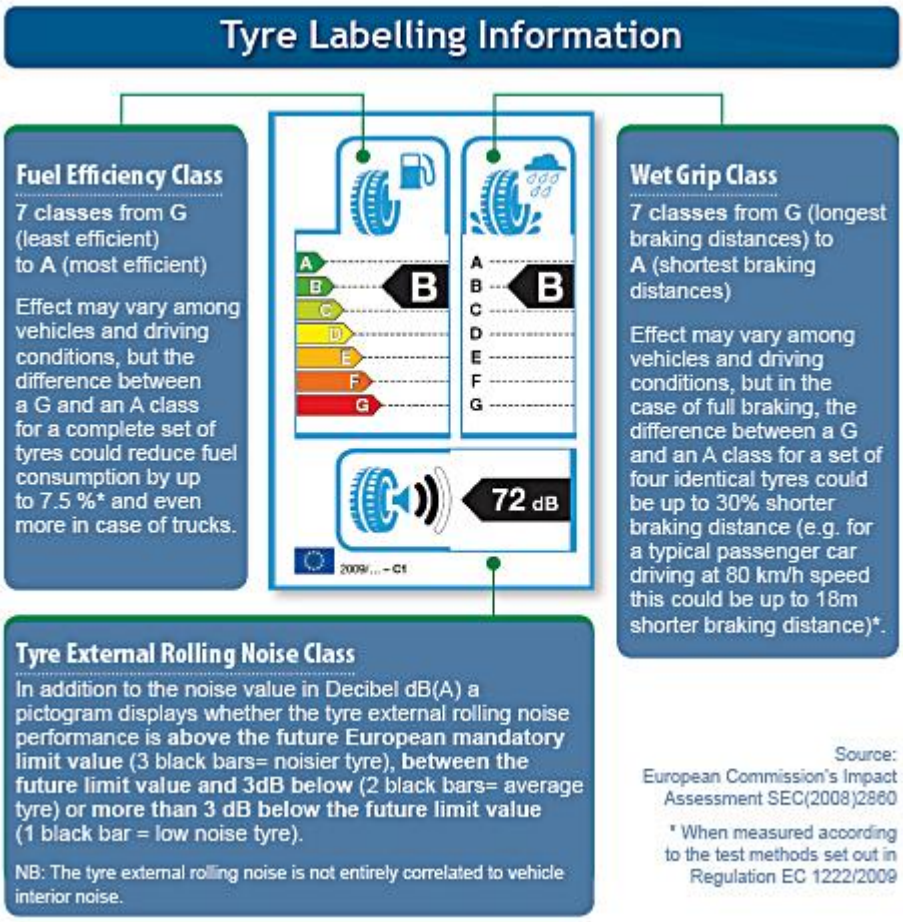
6.3.1 Measure 6.1. Reduce road traffic

Criteria	Comments
Background	The traffic and hence also emissions is expected to increase by about 30% the coming years (from now until 2030) if no special traffic reduction measures are put in place. About 30% of the transport work is in cities, and additional 20% in the near city surroundings, with 50% in the countryside.
Objective	The aim is to reduce the abrasion effect from road traffic on tyres and road paint by supporting initiatives for alternative transport means, or reducing the overall road transport work.
Description	This measure will most likely not be applied based on microplastics alone, but rely on the general transport policy applied by the central and local authorities.
Possible incentives	Stricter air quality guidelines in cities could force local authorities to use different methods to reduce traffic acutely, such as restrictions for certain car numbers on certain days. Urban planning, and general measures in the national transport plans could imply a range of different tools for reaching the goal. A recent Climate Action plan for road traffic in Norway has sketched a package of incentives along several environmental measure scenarios, the most ambitious being reducing private car use in the large cities by 10%, and zero-growth in the rest of the country, with heavy transport overall reduced by 12-18% by transfer to ship and train.
Reduction potential	The overall microplastics reduction potential from such overall traffic measures is limited to around 10-20% compared to existing annual emissions with the current ambitions. Compared to the "business as usual" scenario with

	30% increase to 2030 such measures would have a dramatically positive effect on microplastics emissions. Locally, through for example, car free inner city programmes like in Oslo and Trondheim, the reductions could give more substantial reductions in city dust runoff to local recipients. A 15% or ≈**750 tonnes** emission reduction seems to be within reach.
Cost estimates	The Environmental Agency of Norway has already assessed implementation and enforcement of such traffic reductions, concluding moderate costs regarding private cars. Investments in railway and harbours to increase capacity are necessary for the transfer of heavy transport from the road. The total cost for these measures are estimated as medium, demanding in the order of billions of NOK.
Feasibility	There should not be any technical or legal barriers for implementation. Most methods are well documented and available, and a wealth of plans exist.

According to the European Labelling Regulation (EC/1222/2009) labelling standards have been required.[9] However, the requirements are limited to fuel efficiency, wet grip and external rolling noise. The illustration below shows the criteria of the labelling system today, of which low emissions is not a criteria.

[9] http://www.etrma.org/tyres/tyre-labelling



6.3.2 Measure 6.2. Low emission tyres

Criteria	Comments
Background	Tyres are abraded during use. Theoretically, it should be possible to develop tyres that give away less microplastics. However, there is little information on any initiatives to reduce tyre wear by design. A trade-off is expected between driving safety, tyre road grip, tyre persistence and particle persistence restricting the potential. A change to biodegradable tyres, for example, seems not within reach at the moment, but more durable tyres or tyres with less synthetic polymer content may be options. Tyres designated for winter use are generally of a softer quality than summer tyres, are therefore more readily abraded, and unnecessary use on dry roads and in summer conditions could be avoided.

Objective	The aim is to avoid microplastics from abrasion of car tyres and road paint by supporting initiatives for low emission tyres. Specifically, the microplastic issue, also related to wear and tear, should be added to the labelling system for tyres, across the EU and eventually, internationally. In this way, the issue would be visible and topical within industry and with consumers.
Description	According to the European Labelling Regulation (EC/1222/2009) labelling standards are required[10]. However, the requirements are limited to fuel efficiency, wet grip and external rolling noise. Adding the issue of abrasion/ microplastics to this labelling system, would serve as a strong signal towards both the industry and consumers. The regulation is meant to allow end consumers to make more informed choices when buying car tyres.
Possible incentives	R&D grants and co-funding from the government.
Reduction potential	Small. We do not expect tyre development to give quick gains, so the overall microplastic reductions from this measure depends largely on how far from optimal the tyres in use today are. This would be extremely difficult to find out without substantial independent research. To make tyres that last longer might also require a change in attitude and business models of the producers.
Cost estimates	Moderate
Feasibility	As most of the producers, and markets, are abroad there is a limited chance of Norway reaching this goal alone. We see few examples and little documentation of really promising innovation projects regarding alternative tyres.
Link to other measures	Generic measures like International cooperation would help in implementation. If successful it would lower the need of street cleaning or runoff treatment.

6.3.3 Measure 6.3. Eco driving

Criteria	Comments
Background	All tyres are abraded when used, but there is potential for emission reduction by avoiding unnecessary rough driving, that is e.g. stick to eco-driving.

[10] http://www.etrma.org/tyres/tyre-labelling

Objective	The aim is to avoid microplastics from abrasion of car tyres and road paint by supporting initiatives for Eco driving.
Description	This measure will most likely not be applied based on microplastics alone, but rely on the general transport policy applied by the central and local authorities.
Possible incentives	General awareness campaigns. Product information on tyres. Further incentives for lightweight and low hp engines.
Reduction potential	The tyre importers association in Norway give the following examples on tyre abrasion reduction potentials in single cases of Eco driving[11]: 9% lighter vehicle= 25% decrease in tyre abrasion. 17 % less hp engine= 11% decrease in tyre abrasion In addition reduced speed in general, and in particular at turns and when braking, gives good effect. If many car owners were convinced, there would be potential to, by Eco driving alone, reduce the tyre dust creation by e.g. 10 % or **500 tonnes** per year.
Cost estimates	This is a low cost measure.
Feasibility	A differentiated tax system for cars is already in place. The tyre dealers association is already seeing this as an important measure to reduce air pollution in cities.

6.3.4 Measure 6.4. Improve road surface and sewers to trap and collect traffic dust

Criteria	Comments
Background	According to the Norwegian Public Roads Administration (Statens Vegvesen), dusts from roads mostly end up in nature. Tunnels and the E6 highway close to Gardermoen Airport (due to a fresh water reservoir) are exemptions, whereby the water from the roads is treated. In the inland countryside, road dust would largely be absorbed and trapped in soil along the roads, while in urban environments with impervious surfaces most particles both from building weathering and roads will get washed into the sewer system and transported towards the sea. Some sewers are equipped with silt traps, but the efficiency of these in collecting small and light particles are regarded as

[11] http://www.dekkimportorene.no/slitasje.html

	very low today. There are several promising solutions for creating roads with better runoff management. One applied at warmer climates than in Norway is the use of porous asphalt that allows stormwater and particles to penetrate the road surface and get trapped in a specific filter material below the roads surface. Another option for trapping particles is to direct stormwater into specially designed sedimentation basins or filter systems.
Objective	The aim of this measure is to trap tyre particles and road paint flakes before they reach any waterways.
Description	When it comes to developing more efficient sediment traps to be placed in the city runoff system, there is ongoing work for example in Bergen, to handle this. This work consists of prototypes that function as add-ons to the manholes and sediment traps of the existing system. Natural vegetation buffers and natural filtering are also proven to be very efficient both in cities and the countryside.
Possible incentives	In many Norwegian cities where both surface runoff and sewage is collected through the same sewerage system, any quick fix separating and treating surface water would save the sewage treatment system from running into costly capacity problems.
Reduction potential	It is assumed that about half the road dust in Norway is washed off the roads. A proper containment and filtering system for this would be able to trap a huge part of this, except maybe the finest particles.
Cost estimates	Rebuilding the road and city gutters to better collect and filter rainwater and meltwater would be expensive if it is was done based on microplastics aims alone. The estimated maintenance demand on Norwegian roads is in the order of 1000 billion NOK, with drainage and flood preparedness issues counting for about 10% of this (the major cost is replacement of asphalt) with some 100's of billions being used on water related construction projects around roads in the years to come regardless of microplastic considerations. Particle retainment systems could be incorporated here without adding substantially to costs.
Feasibility	Porous road surface, which is said to be widely used in Japan, Netherlands and Denmark would have low environmental and driving performance in Norwegian winter conditions when roads are filled with ice and snow and could be ruled out for all year roads. As a proper collection, treatment and filtering of collected contaminated roadwater exist only at a very limited number of roads in Norway, it is reasonable to assume that it is generally not possible to apply to old roads where it would require reconstruction. The most feasible option would be to

	look for possible add-ons to the existing roadwater structure, active adding and use of natural vegetation buffers, and to look into the possibility to include it in new road construction.

6.3.5 Measure 6.5. Better road cleaning

Criteria	Comments
Background	Streets in city areas (30% of Norwegian roads) are mechanically cleaned on a more or less regular basis to keep the city air quality within legal limits. Part of this is the regular spring cleaning to get rid of large amounts of dust created by the studded tyres and sand application during the winter. Highways and countryside roads with heavy dust load could also be cleaned. The amount of polymer particles annually deposited from this collected dust in Norway has not been recorded or estimated to date, but there might be potential for improvement in dust recovery. Snow removal activities in Norway outside the cities and towns to a large extent moves the snow with its traffic dust to the roadside. In urban areas snow is frequently moved away on dumpers to designated deposit areas, or dumped directly in the sea to get it off the streets.
Objective	The aim of this measure is to clean the roads more frequently and throughout for particles before they are spread by air or water.
Description	Currently, street sweeper types fall into three main categories: mechanical broom, vacuum-assisted broom and regenerative-air units. Vacuum-assisted and regenerative air sweepers are generally better than mechanical sweepers at removing finer particles. Combined with water flushing integrated in the sweeping machine some studies have shown the effect of a daily cleaning can be compared to the dust removed from the street surface by one rainfall event. Weather you sweep the road in summer season, or remove dirty snow in winter time, the efficiency of the measure would depend on where you then dispose of the traffic dust. Filtering meltwater runoff from snow deposit sites is possible and would make a contribution to avoiding microplastic discharges, contrary to directly dumping snow into harbours. Dumping of sweeping waste near waterways should be avoided.
Possible incentives	Stricter air quality guidelines for cities would force local authorities

	to clean the roads more often.
Reduction potential	The amount of microplastics available to get collected by street cleaning at a given location will depend on the number of dry days, vs rainy/snowy days where the same dust escapes into the city stormwater system. For example, the west coast of Norway usually has around 150-200 days with substantial precipitation per year, while the south eastern Norway there is less than one hundred days. An EU literature review on the efficiency of street cleaning shows that the best available technology is able to remove around 90% of the street dust present at the road surface at a given day, with good efficiency also for particulate matter smaller than 10 micrometres PM10[12]. The average street cleaning machine rarely has higher than 50% efficiency. If all cities, constituting 30% of the transport work, were able to remove 50% of the road dust, this would equate to ≈**750 tonnes** of microplastics per year. This could probably be doubled to ≈1500 tonnes with regular cleaning of highways.
Cost estimates	Moderate costs. Costs could be shared with other programmes.
Feasibility	The technology and methods are available. A scale-up of road cleaning largely depend on budgets.

[12] http://airuse.eu/wp-content/uploads/2013/11/B7-3-ES_road-cleaning.pdf

7 Assessment of reduction potentials and measures for paint

Photo: There is little doubt that polymer based paints spread microplastics both during application, use and maintenance work.

7.1 Conclusions and summary

There are a huge potential of reducing spill of paint particles during painting and renovation work in all sectors, up to 90% of microplastic spill can instead be collected.

In Norway, there is increasing recognition of the need for having some kind of collection and treatment system of paint dust spills. There is a big potential for emission reductions in shipyards, marinas and painting works at buildings and constructions, as well-placed measures today are scarce. For example, only a few shipyards in Norway have water treatment systems, but most do collect some coarse paint dust as hazardous waste. Contractors of huge paint removal jobs on land-based constructions and building have only quite recently started using dust control and removal systems. Norway also has a high rate of do-it-yourself painting and renovation. A poll among recreational boat owners cited in our 2014 microplastics report, shows that less than 40% of boat owners use any professional service for boat maintenance, and only 10% have any access to paint collection systems. Hence, the potential for new measures for reduction of microplastic discharges from paints is high.

Based on dialogue with the paint industry in Norway, Germany and also on a European level (CEPE), this industry, has just recently realized that microplastic pollution can be related to paint. This underlines the need for dialogue and knowledge as a basis for further measures (See generic measures in chapter 5).

Table 7-1 Evaluation scores for measures against paint related microplastics

No	Evaluation of measures - microplastic pollution from: PAINT Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
				Cost per tonne	Available Techniques	Existing initiatives	Sum
		Tonnes reduction	Score 1-3	Score 1-3	Score 0,5-1,5	Score 0,5-1,5	Score 3-9
7.1	Alternative paint formulas	500	3	2	1	0.5	6.5
7.2	Dust and spill control	450	2	3	1.5	1	7.5
7.3	Paint leftovers delivered	100	2	3	1.5	1	7.5
7.4	Water separation and treatment	450	2	1	1	1	5
	TOTAL REDUCTION POTENTIAL	1000	**Out of a total estimated Norwegian discharge at source of about 8.400 tonnes of microplastics (2014)**				

7.2 Gross reduction potentials

Mepex (2014) estimated a total outdoor microplastic emission (c.f indoor emissions) from weathering and removal of various paints to be above 1.000 tonnes per year in Norway, and thus one of the dominant microplastic sources. Shipyards/marinas and renovation of buildings/new constructions contribute about equally to this total amount. A reliable estimate was hampered by not having access to production and sale volumes for Norway, as well as only general and somewhat old numbers for Europe. With updated more reliable information on sale volumes from the Norwegian Paint and Lacquer association[13], there is little discrepancy with the earlier estimates, except for recreational boat paints. There are much lower sales of polymer paints for small boats in Norway than what was assumed in Mepex (2014). However, there are huge import volumes and sales of recreational boats with plastic or fibreglass hulls, and these polymer surfaces are unaccounted for in sale volumes for paint, such as those provided by the paint association.

In our estimates from 2014, we included only the polymer weight (about 25% of the liquid paint, and about 50% of the dry paint) in the volume estimates. Any action to reduce microplastics from paint, for example by treatment/filtering would have to handle the full weight of the paint particles. Also in terms of biological impacts, the effects of the polymers

[13] Maling & Lakkindustriens Forbund

would to a large extent follow the effect of the full matrix. If including the full dry paint weight in the estimate, as opposed to just the polymer content, it would double to a total of 2000 tonnes of microplastics from this source group.

7.3 Description and assessment of measures

We have identified four specific measures that would reduce emissions of microplastics from paint.

7.3.1 Measure 7.1. Alternative paint formulas without polymers

Criteria	Comments
Background	A possible measure would be substitution of paint ingredients away from polymer based chemistry that could end up as microplastics in the environment.[14]
Objective	The aim for this measure is to reduce the consumption of polymer based paints by providing alternative surface treatment strategies to the market.
Description	As far as we understand, there are already alternative paints/ binders without polymers that could be used for many purposes, e.g. traditional wood paints based on vegetable oils, or metal paints based on natural rubber. It should also be noted that not all surfaces need paint at all, for example, indoor walls, furniture and many modern building materials for outdoor use. Discouraging the use of paints for plain decorative purposes is hence one possible way to reduce use of polymer paint. Another is to use paints based on polymer free formulas or new paint development by substitution of polymers with alternatives.
Possible incentives	Public awareness campaigns, directed marketing campaigns from the producers or eco-labelling would be traditional soft incentives to change this market.
Reduction potential	A full swap to polymer free alternatives just for house paints alone would reduce the microplastic discharges by some hundred tonnes per year within the lifetime of the paint, let us say 5-10 years, but

[14] Read more about the constituents of paint here: http://www.essentialchemicalindustry.org/materials-and-applications/paints.html

	with a lag in efficiency due to the standing mass of old paints. Without any exact information we can estimate that ≈50 % reduction is possible. That is above **500 tonnes** reduction of microplastics.
Cost estimates	Not to use paint at all for plain decorative purposes is a low cost measure, but many surfaces require some kind of treatment like paint. Alternative products to the ones creating microplastics already exist to some extent. Changing the use pattern away from polymer based paints is hence a measure that could be applied with good effects at low costs. This is not easy to calculate, but would be a relatively cheap measure for the authorities as the costs are paid by the producers and their customers (i.e. the polluters, ref The Pollution Control Act).
Feasibility	As many modern paints are based on polymers, and there could be other environmental concerns with the substitutes, developing polymer-free paints is a measure that is likely best regarded in a long timeframe with unknown results. However, the experience from the phase out of PCBs and TBTs in paints shows that changes can potentially take place within only a few years.
Link to other measures	Generic measures(perhaps identify the specific measures as well – accreditation etc.) – also this measure in some respects is also related considerably to R&D – perhaps not from the authorities perspective, but in terms of paint producers.

7.3.2 Measure 7.2. Dust and spill control during paint work (air filter, suction e.g.)

Criteria	Comments
Background	The extent of paint dust control at private and commercial paint works on construction sites is highly variable. Some contractors have measures in place, requested in the Terms of reference for larger paint and renovation jobs. However, Norway also appears to have a large grey market for painting works, with slack routines. Data from the Occupational Health Institute STAMI shows that current workers in the construction industry, in particular in small to medium sized companies, often experience high dust exposure. Ship- and boatyards and the construction sector are important actors.
Objective	The aim of this measure would be to stop wet or dry paint spilling

	to the environment during paint works.
Description	The painting industry regards vacuum cleaners connected to paint removal activities as an efficient particle pollution control measure. Sanding machines equipped with dust collection mechanisms are available both for private and commercial activities and are also recommended from a health perspective. To further increase collection efficiency, or as an alternative, it is possible when working with paint abrasion outdoors to also cover the area with a fine mesh net to trap particles and spill.
Possible incentives	Collection of paint spills in commercial paint operations is already a requirement under the Norwegian Pollution Control Act and the Workers Health Protection Act. Greater communication to the various sectors and enforcement of this regulations would be needed to make it work.
Reduction potential	Experience from reducing pollution during paintwork at shipyards in Netherlands is that just sweeping the area after the work is finished reduced the original discharges of paint particles to the sea by about 35%. Further, by also applying some cover and collection mechanisms against air drift of particles to nearby soil and sea during operation it is possible to reduce emissions by 80%. These two methods in concert are thus by Dutch authorities estimated to give a total reduction potential of almost 90%. This would probably also apply to smaller scales, work on buildings, recreational boats and other constructions: there are five registered Blue Flag certified marinas in Norway, which require some collection and delivery of paint waste from boat hulls. The criteria for waste disposal includes a requirement of having disposal bins for paint waste. If this was done at all 2000 boat repair grounds in Norway and 90% of the paint otherwise going to air/soil was disposed of properly it would constitute many hundreds of tonnes. Assuming overall that about 50% of total paint spills today goes to air and soil, this measure with 90% reduction of spills could give a reduction at source of about **450 tonnes** of microplastic emissions.
Cost estimates	For surfaces needing polymer paints, better containment of spills and dust during paint work and renovation is an efficient tool for substantial emission reductions. It is assumed to be cheaper than just treating the effluent water from such sites, but the use of

	both containment and treatment in concert might be needed for a somewhat near 100% emission reduction. The costs are assumed to be moderate, and the law requires the polluter to pay.
Feasibility	There is already regulations requiring this, and several examples of Best Practise and BAT.

7.3.3 Measure 7.3. Paint leftovers delivered as waste

Criteria	Comments
Background	About 40.000 tonnes of decorative and household paint is sold in Norway per year. During do-it-yourself painting in particular, the issue of what to do with paint remaining in paint containers and on your equipment after finishing is ubiquitous. Here, the current choices are more or less, delivering it as waste, rinsing and hence allowing pollutants to enter the sewage system, or depositing the remnants illegally in nearby soil.
Objective	The aims of this measure is to develop better practises for handling paint leftovers.
Description	Instead of disposing of unused paint and rinsing off paint leftovers and equipment to the sewer or soil, a range of alternative disposal methods may be made available such as to depositing all equipment as waste for incineration.
Possible incentives	Refund system? Free delivery as waste?
Reduction potential	The fraction of paint leftovers in containers and equipment varies a lot, but OECD (2009) has as an example stated that about 1.5% of initial paint solids used for private decorative purposes would be leftovers at the equipment and mostly be washed off and end into the sewer. For comparison the brush residues for a professional painter is estimated as 1%. With a total of 40.000 tonnes of paint used annually, of which 25% is binder and with 1% paint brush residue this equals about **100 tonnes** of reduction potential per year.
Cost estimates	
Feasibility	Easy to apply ? – not so sure myself because in addition to public awareness it may also require some new infrastructure (both for consumers and the waste management system) but require a great deal of public awareness.

Link to other measures	Public awareness.

7.3.4 Measure 7.4. Water separation and treatment on site

Criteria	Comments
Background	Where paint work and paint removal work is done at a fixed site, like shipyards, harbours or marinas, it would be possible to apply a better process water treatment to avoid particle pollution. This is best practise in for example, Denmark, Germany and Netherlands but not yet in Norway. High pressure blasting machines have been easily accessible for do-it-yourself work, providing a relatively higher risk of water pollution than earlier techniques of picking/scraping paint off manually or by sander. Also at paint work on building sites and fixed constructions similar methods can be applied, i.e. mobile water treatment equipment.
Objective	The aim of this measure is to collect and filter process water from paint works for microplastics on site before it is discharged.
Description	During paint removal the effluent water is in Norway often allowed to run untreated to the sea or gutter/sewer. For example, only a dozen Norwegian shipyards, and a couple of Norwegian marinas have a sophisticated filtering system on outgoing washing water. Some Marinas also have the Blue flag certification?. In Norway currently, water treatment at yards is implemented simply by having a non-permeable surface under the cleaning area, from which water is directed through a conventional oil and silt trap. The efficacy of this treatment for microplastics has not yet been evaluated. Small and lightweight plastic particles are not likely to be contained in such a system to a large extent and would thus flush through to the sea. Other European nations, such as Sweden and Netherlands have more measures in place, from which we can learn. In Sweden, due to water discharge guidelines for heavy metals, 40-50 marinas have water treatment with particle filtering in place. In Netherlands, particle removal criteria has been in place at the larger shipyards for many years, and evaluated as successful and efficient. An example is the Swedish water management authority guidelines, asking all marinas for more than 30 boats to establish a

	special washing pit with treatment to clean the washing water for particles[15] . A drainage and filtering system covering all the area instead of just a washing and painting pit would probably be fruitful at many sites. Here for example porous asphalt concrete, concrete armed grass or another permeable top layer with a good filtering layer below trapping the particles would be necessary.
Possible incentives	Public funding/innovation seed money to initiatives. Public and private procurement regulations allowing environmentally good solutions to be given high scores when choosing paint job suppliers.
Reduction potential	Experiences from Netherlands is that water treatment can catch about 90% of paint particles otherwise going to the sea from shipyards[16]. Similar or higher efficiency should be expected at smaller scales with less water to treat. If all boat repair grounds and shipyards in Norway collected and filtered their effluent water this would reduce their microplastic emissions by hundreds of tonnes. Mobile water treatment equipment could be applied when doing similar work on buildings or during outdoor construction. Overall efficiency is estimated at 90%, assuming this becomes the standard. Assuming that about 50% of all paint particles spilled in Norway would otherwise be flushed quite directly into the sea with runoff water, this measure with 90% reduction could reduce discharges with about **450 tonnes** per year.
Cost estimates	The cost for applying water treatment technology at shipyards, marinas and larger paint jobs is to some extent known. For example, a large Norwegian waste collection company commercially offers such treatment technology at the following price for measures needed to collect and treat water from cleaning of paint from boats (capacity of treating 1m3 water/hour) at a price of about 300.000NOK[17].

[15] http://renmarina.no/nyhetsarkiv/nyhet/item/svenske-myndigheter-med-nye-krav-til-spyleplasser/
[16] 2015 report on shipyard emission factors, Dutch environmental authorities.
[17]

	Price estimate for a small scale treatment system for paint washing water: Ground construction and pipe system 100.000NOK Compete filtering system unit (capacity 1m3/hr) 115.000NOK Technical shed if needed 110.000NOK Maintenance (replacement of filter material after 250-300 washes) 3-4000NOK Collection of sludge (e.g. 1 tonne, 2 hour work) 10.000NOK Such a system can also be applied as a mobile solution, or up scaled to any treatment capacity by adding treatment modules or adding temporary water storage like basins or tanks to handle discharge peaks until they can be filtered through the system.
Feasibility	The technology exists and is implemented as best practise in shipyards. The Netherlands use the required technology and methods already. Two Norwegian marinas are at present testing out the Swedish water filter system with a proven good efficiency for removing heavy metals to below the water emission guidelines. Also other more makeshift treatment systems are currently being? tested at other marinas[18]. The efficacy of these treatments for microplastic removal is not documented but presumably good as they should be within the same paint particle matrix as the heavy metals. A challenge for many smaller shipyards and smaller boat maintenance grounds (e.g. less than 150 boats) in Norway though is their location, often on landfills with gravel surfaces near the high tide mark. Paint maintenance work is normally not done at a single spot of the facility, but over most of its area. One reason for this is the seasonal nature of recreational boating, with a hectic boat landing period in autumn, and a boat painting period around Easter. When tens of boats are landed on the same day the traditional logistics does not allow all paint washing to be done at a single washing pit. Any heavy rain or flooding event would swiftly wash huge amounts of paint particles into the sea from these areas.

Source: Norboat, webpage:
file:///C:/Users/pes/Downloads/NGI_Axon_Spyleplasser140919_vF_1%20(2).pdf

[18] Pensjonistene i Sandefjord har laget et renseanlegg som enkelt kan gjøre båtvasken mer miljøvennlig. – Nesten overalt spyles bunnstoffet og annen møkk rett ut i sjøen, sier de.
http://www.nrk.no/vestfold/renser-marinaen-1.12625824

	There is likely to be some resistance among professional actors like shipyards, marinas and construction firms against applying too strict a paint dust control policy. For example, it is stated by a recent Shipyard Industry Association report19 that the finer paint particles are, to a large extent flushed directly into the sea, and that the industry don't yet find it cost worthy investing in more efficient water treatment or dust collecting systems. Despite this line of thought also enabling risk of negative competition among actors in Europe and inside Norway.
Link to other measures	See measures Road surface and Water treatment.

19 Norsk Industri (2012)
http://www.norskindustri.no/siteassets/dokumenter/bestepraksisverft2012.pdf

8 Assessment of reduction potentials and measures for textiles

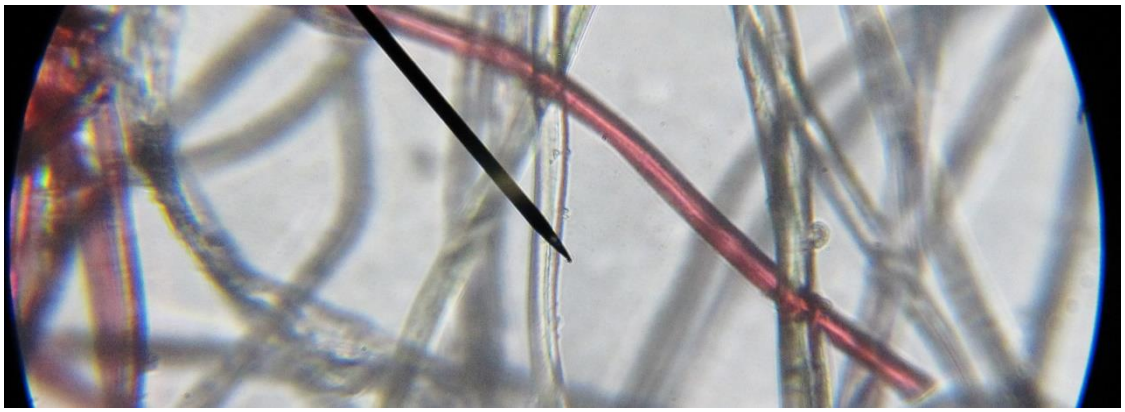


Photo: Microscope magnified fibre lint shed by a polyester fleece sweater.

8.1 Conclusions and summary

This report describes and evaluates measures to reduce the amount of plastic microfibers from textiles ending up in effluent from laundries. A new standard test method for measuring the loss from textiles, while not achieving emission reductions, is regarded as a basic need that must be developed.

There are two main strategies for reduction of the emissions analysed, one about production of textiles with low loss, and the other about filter systems in washing machines. Both measures are not mutually exclusive and combined achieve a better outcome. Improved product design and production methods have the highest score, but filters in washing machines can probably provide a similar if not better outcome.

General reduction in use of synthetic textiles and substitution with renewable materials will also have an impact, but this measure will also have other implications outside the scope of this report. Improved washing detergents is a measures mentioned, but is not evaluated because of lack of information.

Table 8-1 Evaluation scores for measures against microplastics of textile origin

No	Evaluation of measures - microplastic pollution from: Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
		Tonnes reduction	Score 1-3	Cost per tonne Score 1-3	Available Techniques Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
8.1	Reduction in use of synthetic textiles						
8.2	New test method	-	1	3	1,5	1,5	7
8.3	Improved design/production	**280**	2	3	1,5	1,0	7,5
8.4	Filters on washing machines	**350**	2	2	1,0	1,0	6
8.5	Improved washing detergents						
	TOTAL REDUCTION POTENTIAL	**490**	**Out of a total estimated Norwegian discharges at source of 8.400 tonnes of microplastics (2014)**				

8.2 Gross reduction potentials

Mepex (2014) estimated a total synthetic microplastic fibre loss from household laundry to wastewater of 600 tonnes a year. Different estimates vary from 280 to 980 tonnes per year based on different sources analysing fibres in wastewater. The figure of 600 tonnes of shredded fibres in Norway equates to 800 000 fibres per person per year. In general, the requisite knowledge to appropriately aggregate data to a national mass flow calculation is limited, and this result is considered approximate and as a first indication.

New international research programs have started up and will soon give more information about the amount of fibres loss from textiles during the washing process and the factors most relevant to fibre loss.

It should also be noted that textiles have additional loss in daily use that appears as indoor dust and is directly shed during outdoor use.

In the last part of the report from 2014, it was indicated that 90% of microplastic fibres are removed in wastewater treatment plants and end up in sewage sludge. This gave an emission from plants of 60 tonnes per year. In addition, amounts from commercial laundries were estimated at 100 tonnes with an emission of 50 tons/year after wastewater treatment. In total emission direct to lakes and sea was estimated to 110 tonnes/year.

The Norwegian sewer and waste-water treatment systems will not remove up to 90 % of microplastics from household laundry. The following factors will have influence:

- Up to 5 % loss via overflows during rainfalls.
- 15-20% loss in transportation system due to leakages in pipes and drains etc. A part of this may directly lead to the storm water system[20].
- About 60 % of households are connected to chemical/biological treatment plant[21] that most probably will give a retention effect up to 90 % for particles above 20 micron.

In total, this leads to a new estimation; only 50 % of 600 tonnes per year are removed from the wastewater. According to this, about 300 tonnes are the total emission and thus the potential for reductions.

Anyway, under Norwegian conditions 86 % of sewage sludge is treated and used as a soil conditioner and fertilizer, mainly in agriculture. The appearance of microplastics in sewage sludge shows that waste water treatment is not a complete solution. Potential for reduction should therefore be calculated from the amounts from source

- 600 tonnes from private households
- 100 tonnes from commercial laundries

This project cannot refer to new studies that lead to updated estimates for generation of synthetic textile particles from private household laundry. A comparison with other studies is presented in table 8-2:

Table 8-2 Comparison of per capita generation of synthetic textile microplastic particles

	Mepex Kg/capita	Cowi Denmark[22] Kg/capita	Eunomia EU[23] Kg/capita
Household textiles to sewer	0,12	0,04-0,18	0,03-0,10
Industrial laundries to sewer	0,02	-	-
Total to sewer system	0,14		

[20] Based on dialogue with Terje Farestveit in Norwegian Environmental Agency
[21] Gisle Berge: Report SSB 2014/41Kommunale avløp Ressursinnsats, utslipp, rensing og slamdisponering 2013. Gebyrer 2014
[22] Microplastics, occurrence, effects and sources of releases to the environment in Denmark. Cowi for Danish Ministry of Environment, Aug. 2015
[23] Study to support the development of measures to combat a range of marine litter sources, WP2, Eunomia, sept. 2015

Total to river/lake/sea*	0,06	0,02-0,05	0,003-0,01

* updated estimations for Mepex

8.3 Description and selection of measures

When examining different measures for reduction of microplastic fibres from textiles in washing machines ending up in effluent, representatives from the Norwegian textile branch gave valuable input. A small workshop was organised as a part of the process. Table 8-3 below shows the different measures considered. We have chosen to describe and evaluate 3 of the measures in detail.

Table 8-3 Possible measures for textile fibres

No	Measure	Comment
8.1	Reduction in use of synthetic textiles	Outside scope
8.2	Standardized method for measuring loss	Basis for other measures
8.3	Improved design and production methods	Effective measure
8.4	Washing machine with filter systems	Effective measure
8.5	Improved washing detergents	More unsure effect

Reduction of textile use generally, and synthetic textile especially, can be an efficient way to reduce the high environmental impact from production and use of clothing and other household textiles. The total consumption in Norway has increased dramatically during the previous few decades as more cheap products of low quality, often based on polyester and other synthetic fibres, have become available. There are environmental challenges with both cotton and synthetic fibres and it is outside the scope of this project to propose a general substitution away from synthetic fibres. In the total life-span for textiles, the reuse of worn textiles in other parts of the world should also be taken into account when thinking about the complete cycle of microplastic release.

We have in this report also chosen not to go into measures regarding washing detergents as a measure to decrease fibre losses in washing machines.[24] This is a topic in other studies and information about possible effects is not available.

[24] MERMAIDS, LIFE13 ENV/IT/001069, Mitigation of microplastics impact caused by textile washing processes, project presented in Cologne 23 November 2015

8.3.1 Measure 8.1. Reduction in use of synthetic textiles

Outside scope.

8.3.2 Measure 8.2. Standardized methods for measure textile fibre loss

Criteria	Comments
Background	The project has identified a need for a standardized method to measure synthetic microfiber loss from textiles before putting them on the market. A method for measuring fibre shredded from textiles will be useful to define standards manufacturing textile fibres, garments and fabric. This can be important for environmental responsible actors to avoid use of fibres and production methods that will result in products with a high potential for microplastic emission. Knowledge about this issue is crucial to push textile development and use in the desired direction.
Objective	The aim is to develop a standardized method to measure the amount of shredded fibres that will release during washing process in the use-phase of the different textile products under Norwegian conditions and to implement the method.
Description	The development of this method can build on experience from already existing methods to carry out other washing tests under Norwegian conditions (water, temperature, detergents, time, etc.). Also effects from degradation under sun-light and temperature in specific textile laboratories can be included. The essential part of the method is to register the loss of fibre, either by weight reduction of the product or by effective filtration and characterisation of the water effluent. For textiles with different fibres, including biodegradable fibres, more detailed analysis of the fibre content is needed. Other impurities that can have effect on results should be avoided. The method will require considering the entire life cycle of the textile, for example, repeated washing and textile disposal.
Possible incentives	The incentives towards this measure can be based on financing from authorities or public research funds. This could also be organized and developed within Nordic Council of Ministers (NCM) working from green growth perspectives. The project can be organized with a broad textile panel taking part in demonstrating the methods on their products.
Reduction potential	The method and system for measuring the shredded fibre from textiles will not directly give results, but is essential in order to measure the variations of textile fibre release and understand the mechanisms explaining this release over time.

Cost estimates	To develop a method that is tested and ready for implementation can be organized as a project within a specific cost frame. First estimation is 2 mill. NOK as an investment. Price for using the testing method will depend on the actual textile quality and the belonging testing procedure. Loss of shed textile will be an integrated part of other testing methods, and there is too little information to give a cost estimate.
Feasibility	There should not be any technical barriers for implementation, but there is a need to develop and test the method properly. If the method is to be a basis for a new regulation to avoid the use of textiles with high losses of shed fibres, this will result in greater incentive for development in order to unambiguously define a standard.
Link to other measures	This measure is linked to measure 2 Improved design and production methods as a necessary tool set focus on fibre loss and to reduce the loss of shredded fibres from textiles.

8.3.3 Measure 8.3 – Improved design and production methods

Criteria	Comments
Background	It may very well be that a limited part of the market for synthetic fabric for specific purposes represents a substantial fraction of the problem. This may be products treated in such a way that fibres on the surface are weakened or destroyed and potentially therefore will release more fibres than if not treated. With more knowledge about this problem and the reasons for the release of fibres, there can be normal standards defined for release, which make it possible to avoid the use of textiles with high losses.
Objective	The aim is to avoid use of textiles that generate high levels of shredded fibres during use and washing
Description	This measure depends on a good method to measure the amount of shredded fibres per weight unit fabric (measure 8.3.1). Putting this on the agenda among Norwegian market supplier it is assumed this will lead to new requirements for design and textile products from suppling factories. Norwegian companies is a parts of international supply chains and can lead to effects in other markets. Choice of material for different applications should be considered. This will represent a new parameter among several other connected to environmental and social aspects in productions of garment, fabric and final textile product. The development can be divided into following parts:

	1. Supporting and taking part in research projects to obtain more information about the variation in loss from different products under different conditions and the factors affecting this. 2. Encourage and educate professionals based on different information channels and organized by entities with high credibility. Cooperation with press and different organizations. 3. Develop a system for transparent documentation from standard tests methods to document fibre release.
Possible incentives	The incentives towards this measure can either be based on market regulations from authorities, or based on volunteer agreements and commitments from textile producers taking responsibility. In both cases it's possible to define recommended maximum levels of release of synthetic fibre, based on common methods developed in (8.3.1).
Reduction potential	It is difficult to predict the possible effect of this in both the short and long term. This would only effect new textiles put on the market and will therefore have greater effect as time goes on. The measure can in the best case cover 80 % of the market. Direct import (by internet) and other parts of the textile market are hard to regulate. Based on discussion in workshop and new initiatives we assume roughly that it's possible to substitute and change production methods so a 50 % reduction can be obtained for 80 % of the textile market. This can result in a reduction of 40% or about 280 tons/year based on calculation for 2014.
Cost estimates	The costs connected to these changes in design and production methods can be calculated differently depending on the incentives chosen by the authorities. To implement and put in force a regulation and belonging method to measure and document the level of shredded fibres will result in investment costs and operational cost in budgets for official administration(s). The control seems as it should be the responsibility of producers and importers, comparable with the regulations on the flammability of children clothes. A rough estimate can be 3 mill NOK in investment and 1 mill in operation yearly. Changes in production costs and market prices may result from this measure, but this is not considered to be particularly relevant, even when substituting textiles. There may be some low-cost and low quality textiles that are prohibited or avoided in the market and there. There will most likely be some higher cost for alternatives in the use phase. This can give a positive effect on the very high consumption of textiles with short lifetime.
Feasibility	There should not be any technical barriers for implementation of improved design and production methods.

	The need for changes in legal framework will depend on the chosen strategy. These should be compared with other relevant regulation on textiles already in place. In general national regulation can have only a limited effect and international regulation will be difficult to develop.
Link to other measures	The need for regulation should be considered with the possible legal instruments to implement filters on all washing machines.

8.3.4 Measure 8.4 – Filtering system on washing machines

Criteria	Comments
Background	All washing machines will normally have a filter system to remove items that can block the water flow and create problems. These are so-called lint-traps. These filters should under Norwegian conditions be emptied about 10 times a year according to recommendation, but in practice are generally only a few times a year. The project has identified improved lint filters already in use in Japan. Information about how effective these filters are or the different pore size in the filter mesh, has so far not been found. These filters make a cake of lint similar to the ones from drum driers. These are most probably not disposed of in the sink and are probably put in the rubbish. These filters need more maintenance and require to be emptied more often.
Objective	The aim of his measure is that all new washing machines should as a standard be delivered with an effective filter system to remove microfibers shed from synthetic textiles. The filter will remove all kinds of fibre and particles from washing water. There should also be available solutions to install a separate filter on the pipe for grey water emitted from washing machines.
Description	For industrial purposes there may be different solutions for machines for synthetic fibres Vs machines for cotton/wool. The development should be bought forward by the suppliers of new washing machines during the design phase of new machines. Also considering easily implemented systems when it comes to cleaning filters, having effective indicators to ensure cleaning occurs and avoiding removal of filters. There are already solutions available in the market that can be adapted to the environmental challenge of microplastic. Filtering system development may be divided into the following parts: 4. Supporting and taking part in research projects to obtain more information about possible filter systems and their effect on removing the fibres from washing water.

	5. Education of professionals based on different information channels and organized by entities with high credibility. Cooperation with press and different organizations. 6. Develop a system for transparent documentation from standard tests methods to document fibre capture.
Possible incentives	The incentives towards this measure can either be based on regulations from authorities or based on volunteer agreements and commitments from suppliers taking responsibility. In both cases it's possible to define common requirements regarding effluents from washing machines.
Reduction potential	It is difficult to predict the possible effect of this in the short and long term. Even if all new washing machines are installed with effective filters to remove small particles from 10 micron, there is a question about how this will be followed up by citizens. The best solution would be that effective filters have to be in place in order to operate the machines. The measure can in best case cover 75 % of the market at 5 years after introduction of new regulation. The average life-time for washing machines in Norway is about 7 years. We assume it's possible to reach a 50 % reduction with this measure, based on the total potential amount in effluent water. This can result in a reduction on 350 tons/year considered as an individual measure.
Cost estimates	To implement and enforce a regulation about filter system in washing machines, investment costs and operational costs in budgets for the official administration are required. Producers and importers should be responsible for control during manufacturing and sales. A rough estimate can be 3 mill NOK in investment and 1 mill in operation yearly. The higher production costs for the washing machines will vary depending on how easily the new filter can be adapted and other factors. Rough estimates from other sources are 500-1000 NOK per machine, or about 10 % increased price. At the same time this can represent lower risk for clogging in waste water pipes. In Norway with about 250 000 new washing machines yearly the extra cost (directly to consumers) may be 125-250 million NOK yearly.
Feasibility	There should not be great technical barriers for implementation, but this has to be considered by the producers. Security to avoid blocking and floods would have to be solved in a simple and safe way. There should be legal framework in place (Pollution Act) to develop specific new regulation for washing machines as a product group.

	Washing machines manufacturers in Europe directly and indirectly through national organizations are organized in CECED in Brussels. It seems relevant to work with industry to develop this measure.
Link to other measures	It may be relevant to discuss a regulation on washing machines in connection with regulation on textile products in order to choose one, or a combination, of them. Our initial assessment is that it seems more likely to be effective if regulation was focused on washing machines and more volunteer actions for textile products.

Table 8-4 Generic measures adapted to textiles

Generic measures	Relevance to textile area
Eco-labelling systems	A new standard test method for release of fibres from synthetic textiles can be integrated as a part of existing initiatives like the Higg-Index, developed under Sustainable Apparel Coalition. This is a self-assessment tools empowers brands, retailers and facilities of all sizes, at every stage in their sustainability journey, to measure their environmental and social and labour impacts and identify areas for improvement. Higg delivers a holistic overview of the sustainability performance of a product or company. Including microplastic in a system for environmental labelling may be a challenge based on an already demanding situation with a lot of possible conflict of interest. Other eco-labelling systems (either existing or new) that incorporate microplastic information may be considered.
Public awareness campaigns	First of all the education can start up with information about per capita emissions for clothing/textiles actually is and how this is added up to a national emission. Based on existing and new information that will become available in the near future, it will be possible to develop guidelines for the public to choose products with materials and quality that can reduce the problem with microplastic fibres from textiles. This can be used both by commercial companies in their product information, but also from NGOs or authorities. This can for example cover: - Material choice based on best practice - Reducing of laundering frequency - Products with longer life-span and reduce consumption

	- Lower washing temperature
Requirements in public procurements	A lot of public entities buy a lot of textile products, washing machines and also services connected to textile washing. There is a possibility to develop guidelines for such institutions and encourage the entities to define relevant requirements for textile microplastic fibres/content. Requirements can also be implemented in environmental certifications standards.
Commitment/ partnership for industry and authorities	In order to implement the different measures there will be need for a better platform for cooperation.
Research activities	There is need for more research activity in this field to support the measures described. This covers also development of test methods and standards for textiles and washing machines. There is a need to develop the national knowledge based on research under Norwegian conditions and to involve environmental authorities in the development. International cooperation and network should also be an integral part of this.

9 Assessment of reduction potentials and measures for cosmetics and detergents

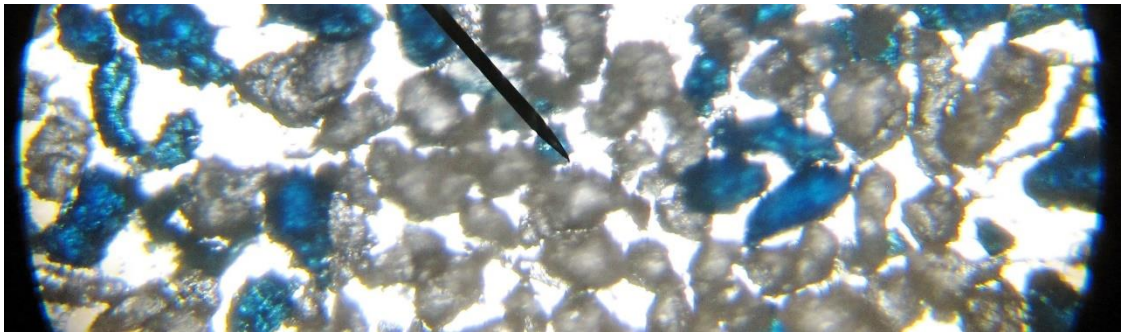


Photo: Microscope magnified plastic microbeads from a facewash soap bought in Norway

9.1 Conclusions and summary

This chapter concentrates on cosmetics and measures to replace microbeads by alternative solutions. Detergents are not included:

- Recent reports from Denmark (COWI) and Germany (Nova- Institute) also list some detergent products and abrasive blasting media as additional, but minor sources for microplastic pollution. In this report, we do not discuss these products further. However, both product groups use microbeads intentionally as an active part of the product . Measures described in this chapter are thus relevant for detergents and abrasive media as well.

According to the previous Mepex (2014) report, emissions from cosmetics are limited. The industry has already committed to replacing remaining microbeads in cosmetics by 2020. A key measure will be to follow up this process and require that industry report their results. In addition, part of this dialogue should require consideration of it assessment of the environmental impact of the new materials in cosmetics is needed. This measure can be supported by other proposed measures, such as following the development in the USA and within the EU, inclusive of possible bans. Nordic Ecolabelling as well as public procurement and positive guidance from NGOs, as it progresses, can also support the process and the push to combat the microplastic pollution from cosmetics.

As well as abrasive microbeads, cosmetics also contain polymers, beyond what sometimes is regarded as microbeads/ microplastics. For these polymers, we still need more knowledge and research, inclusive of the volumes used. Industry admits that they do not have any replacement solutions for these polymers.[25] The proposed measure here also includes following the development in the EU and USA closely, both on the microplastic definitions in general and specifically on European measures related to these polymers.

Table 9-1 Evaluation scores for measures against microplastics from cosmetics

No	Evaluation of measures - microplastic pollution from: Cosmetics Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
				Cost per tonne	Available Techniques	Existing initiatives	Sum
		Tonnes reduction	Score 1-3	Score 1-3	Score 0,5-1,5	Score 0,5-1,5	Score 3-9
9.1	Follow up industry commitment in Norway		2	2	1,5	1,5	7
9.2	Follow up on European and US development		2	1	0,5	1	4,5
9.3	Ban the use of microbeads		2	1	0.5	0.5	4
9.4	Research on alternatives		2	1	0.5	1	4.5
9.5	Eco label and Public procurement		1	2	1	1	5
9.6	Stimulate positive guidelines		2	3	1	1	6
TOTAL REDUCTION POTENTIAL		**40**	**Out of a total estimated Norwegian discharges at source of 8.400 tonnes of microplastics (2014)**				

9.2 Gross reduction potentials

9.2.1 Summary of gross potentials from Mepex report 2014

Based on several assumptions we estimated these emissions to 8 grams per capita, e.g. 40 tonnes at the sources, per year for Norway. These estimates are more or less in harmony with similar studies, see chapter 2. More information beyond these prognoses is presented below concerning developments in the near future and other polymers used in cosmetics.

[25] Renner, G., Cosmetics Europe at EU WS in Brussels on 20 October 2015

9.2.2 Adjustments and prognoses based on new knowledge

Cosmetics Europe made in October 2015 a recommendation to discontinue, in wash-off products as of 2020 the use of synthetic, solid plastic particles used for exfoliating and cleansing that are non- biodegradable in the marine environment.[26] Based on this commitment Eunomia has estimated that microbeads related to some cosmetic products, rinse off products and toothpaste, will be reduced during the next five years. As illustrated in Figure XXX, the total volumes of discharges from these specific product groups should be substantially reduced. Both the Cosmetics Europe commitment and the fact that there are alternative materials available make these reduction estimates reasonably robust.[27]

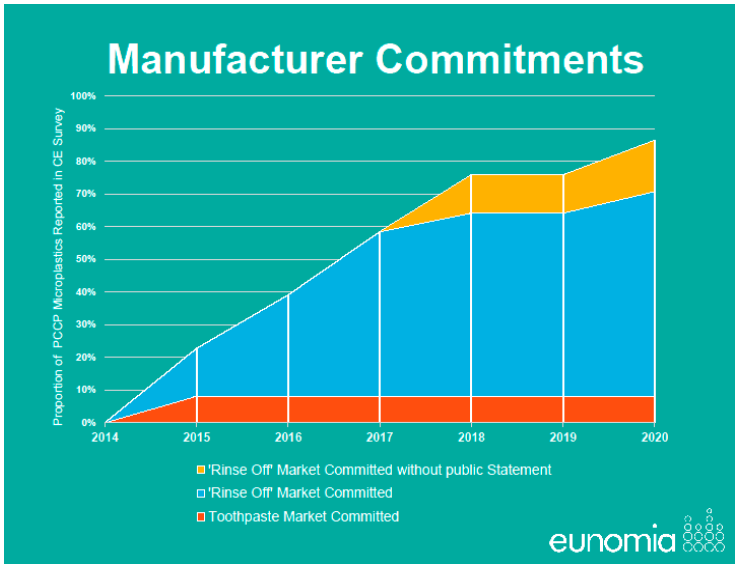


Figure 9-1. Combined cumulative market commitments within EU, based on reported microplastics tonnage from Cosmetics Europe survey, source: Eunomia.

9.2.3 Additional emission sources

Despite these reasonably robust reduction estimates, there are uncertainties related to the emissions from other personal care products, as there are no specific industry data. Furthermore, industry also admits that replacements/ alternatives do not currently exist. Eunomia has, in their draft report illustrated this.

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[26] Cosmetics Europe, press release 21 October 2015

[27] Hann, Simon, Eunomia. 5 September 2015, Study to support the development of measures to combat a range of marine litter sources. WP 2: Preliminary scoping exercise of options to achieve a phase-out or ban of microplastics in cosmetic products. Report for DG Environment, European Commission.

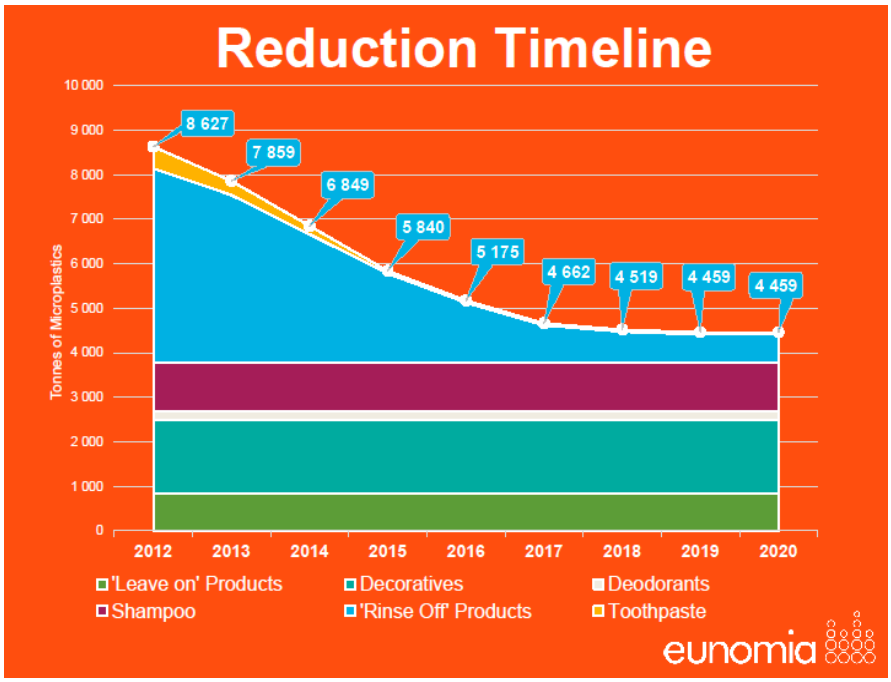


Figure 9–2. EU reduction timeline for different cosmetic products in Europe, source: Eunomia

9.3 Description and selection of measures

Table 9-2. Possible measures for reducing microplastics from cosmetics

No	Measure	Comment	Reference
9.1	Follow up industry commitment in Norway	Commitment on microbeads made in 2015	Cosmetics Europe
9.2	Follow European and US development on other polymers	Replacing other polymers in focus	USA, EU
9.3	Ban the use of microbeads	As back up or strengthening of 9.1	Sweden, USA, EU
9.4	Research on alternatives	Replacing other polymers in focus, as part of 9.2	
9.5	Ecolabel and Public procurement	Strengthening 9.1	Nordic Eco-label
9.6	Stimulate positive guidelines	Promoting 9.1	FFI in UK

We describe and assess six specific measures and related generic measures.

9.3.1 Measure 9.1. Follow up industry commitment on cosmetics

Criteria	Comments
Background	As most cosmetics used in Norway are imported, a first measure will be to follow up the commitment from the cosmetics industry in Europe, also supported by The Norwegian Cosmetics Association: Cosmetics Europe made the following recommendation on 21 October 2015: "*In view of the public concerns expressed over plastic debris in the marine environment, and given the availability of alternative materials, Cosmetics Europe recommends its membership to discontinue, in wash-off cosmetic products placed on the market as of 2020: The use of synthetic, solid plastic particles used for exfoliating and cleansing that are non-biodegradable in the marine environment".*
Objective	The aim of this measure is to oversee that the industry reaches its goals of discontinuing use of plastic microbeads as of 2020 and finds sustainable alternatives.
Description	The follow up can be based on a close and structured dialogue with The Norwegian Cosmetics Association/ KLF/Kosmetikkleverandørenes Forening, who organizes the Norwegian industry, trade and importers. KLF is member of Cosmetics Europe. Norwegian authorities should require follow up reports and documentation from KLF and main retailers on the use of microbeads and polymer fillings in all cosmetic products and on the use and the environmental impacts of materials replacing currently used polymers. In addition, as KLF's sister organization, the Norwegian Cleaning Suppliers Association/ Vaskemiddelleverandørenes Forening, should be followed up in parallel.
Possible incentives	PR for industry.
Reduction potential	40 tonnes of microplastics per year.
Cost estimates	Low. We believe such commitments from industry can be very efficient with low costs for society.
Feasibility	This initiative exist already. Regarding this measure, we are aware of the fact that organizations like Cosmetics Europe cannot instruct members/ companies in the market and can only provide guidelines/recommendations to members. There are also several constraints to such commitments due to

	competition regulations, which can undermine commitments, however beneficial. This means that other measures can be used as a backup and reinforcement. The environmental impacts of the replacements should be examined as some quick fix solutions, such as “biodegradable plastics” alternatives can have negative impacts too.
Link to other measures	Generic: Innovation, Research and Development.

9.3.2 Measure 9.2. Follow European and US development on other polymers

Criteria	Comments
Background	Lack of alternatives is a key barrier for replacement of other polymers in cosmetics. Further research is needed, first on better assessments of the volumes used in the market, the environmental impacts of these polymers and finally on alternative materials and solutions. Particularly given that industry acknowledges the lack of alternatives currently available. Industry in both the USA and in Europe is reportedly working hard on these issues. In the USA, different kinds of bans are introduced in different States and at a Federal level, providing a strong incentive for manufacturers to develop alternative solutions.
Objective	Monitor legislation in USA and its efficacy. Monitor the development in Europe and the USA of replacing non-microbead polymers used in cosmetics and promote these solutions.
Description	We believe this research best can be organized and financed internationally, inclusive of the EU. This also includes further discussions on definitions of microbeads/microplastics in cosmetics ingredients.
Possible incentives	Commercial incentives, both market driven, Ecolabel driven and as a result of bans or possible bans. International agreements, OSPAR and others.
Reduction potential	The remaining polymers used in cosmetics.
Cost estimates	Costs included in OSPAR dialogue as a generic measure and dialogue with cosmetic industry (measure 9.1)
Feasibility	OSPAR is a relevant platform for this monitoring.

Link to other measures	Generic measures as 5.10 Research and development and 5.2 voluntary commitments

9.3.3 Measure 9.3. Ban on microbeads in cosmetics

Criteria	Comments
Background	Some States in the US have decided to ban the use of microplastics in cosmetics. On 31 December 2015, President Obama signed an amendment to the Federal Food, Drug and Cosmetics Act to ban cosmetics that contain synthetic plastic microbeads beginning on 1 January 2018. [28] The Swedish Chemical Agency, Kemikalieinspektionen, on 15 January proposes a ban as of 2018, on cosmetics containing microbeads. The agency considers this regulation as an addition to industry commitments. [29]
Objective	The aim of this measure is to prepare a possible ban of microbeads if it is not voluntarily phased out by the industry.
Description	Based on more knowledge about other polymers in cosmetics and the progress from the voluntary industry commitment, a possible ban might be evaluated later.
Possible incentives	A ban could be based on the Norwegian Pollution and Product Control Acts.
Reduction potential	40 tonnes or more depending on the definition.
Cost estimates	Low cost
Feasibility	A ban with enforcement can be efficient A ban must be based on a possible long and complicated political and legal process.
Link to other measures	Generic measure 5.4 Restrict use of microbeads

[28] https://www.govtrack.us/congress/bills/114/hr1321/summary

[29] http://www.kemi.se/nyheter-fran-kemikalieinspektionen/2016/kemikalieinspektionen-foreslar-begransningar-for-plastkorn-i-kosmetika/

9.3.4 Measure 9.4. Research on alternatives

Research and development is a generic measure, also relevant for cosmetics. Research comprises both alternatives to microbeads and other polymers used in cosmetics.

Industry is already active developing microbeads alternatives. However, we need more research on alternatives for other polymers used and on the possible impacts of the substitutes for both kind of alternatives. This might include impact on the sewage system as well.

Financial support for such research programmes may speed up developing relevant replacements.

9.3.5 Measure 9.5. Eco- labelling and public procurement

Eco- labelling is also a generic measure, see chapter 5.8. The Nordic Eco- label is already active and since 2014, The Nordic Eco- label requires that cosmetics for skin and hair do not contain microbeads. This is message is also promoted in media.

Measure 5 includes further Nordic joint efforts to develop the existing competence and criteria and even active promotion of the issue - towards industry, users and consumers. In this way, this measure indirectly stimulates public procurement, for example from hospitals and hotels.

Eunomia proposes the same measure in their report as well: "*Eco-labelling on such consumer products can be an efficient measure to promote better products and develop both competence and dialogue".*

This measure might speed up the replacements based on industry commitments, e.g. measure 1 and 2.

9.3.6 Measure 9.6. Stimulate positive guidelines

Criteria	Comments
Background	Some NGOs have been very active on the issue of microbeads, for example, combatting the use of microbeads in all cosmetic products. [30] Some NGOs are now also developing positive guidelines. The idea is that consumer awareness and practical positive information

[30] Beat the Microbead is an initiative supported by 76 NGOs from 35 countries.

	shall be an incentive for the producers to substitute the microbeads by alternatives.
Objective	The aim of this measure is to make sure that consumers have access to updated information about which products do not contain plastic microbeads. This information should be independent of product labelling, inclusive of all products and not just the few products with the Nordic Eco-label.
Description	The NGO Fauna and Flora International (FFI) started its work on marine plastics in 2013, by creating a product database of UK face scrubs. From this, FFI now develops a consumer guide indicating which of these scrubs are free from solid plastic ingredients (defined as six key polymers): "*The Good Scrub Guide*". As with other organisations across Europe, FFI also takes part in the '*Beat the Microbead*' coalition. FFI maintains the ingredient/ product lists for the UK and Australian data behind the website/app, listing whether products are either solid-plastic-free, contain plastics, but are committing to phase them out or contain plastic and have not committed to phasing them out.[31] Also other NGOs are now switching from combatting products and companies selling cosmetics with microbeads to guiding consumers positively on microbead- free products available.
Possible incentives	The Environment Agency could support the NGO database with product information and funding. In addition, promote the NGO initiatives.
Reduction potential	n.a.
Cost estimates	Low cost measure.
Feasibility	The initiative already exists, accessible via the web or Apps.
Link to other measures	9.1 Industry commitment, 9.5 Eco-labelling,

[31] Daniel Steadman, FFI, personal communication 7 December 2015

10 Assessment of reduction potentials and measures for pellet losses

Photo: Plastic pellets (mermaid tears) found in large volumes on Norwegian beaches 2015.

10.1 Conclusions and summary

Plastic pellets (also called 'nurdles'), virgin or recycled, are used as raw material for plastic converters when producing plastic products. Lost pellets, from plants or during transport, can attract and concentrate background pollutants to high toxic levels. Nurdles can also unintentionally enter marine and terrestrial food chains (citation).

The Mepex estimates in the 2014 report on gross potential for reduction of pellet loss, from industrial plants and transport in Norway, were based on international assumptions from literature in 2014, as a worst case scenario.

- The Cowi study in Denmark, based on input from the plastics industry in Denmark, indicates that the losses can be lower than the Mepex estimates.
- Beyond the Cowi report, it has not been possible to obtain any data from industry in Norway or other Nordic countries. We thus keep the estimates from 2014 as a basis. However, the estimates are uncertain, further studies are needed.

We have assessed four measures. All of them we can be regarded as generic, described in general in chapter 5. The four measures are roughly assessed.

It is difficult to estimate the net emission reduction potential for each measure. However, we believe a combination of all four measures will result in synergies and thus a high score for the total package.

In general, a voluntary commitment is a good basis for motivated actions and innovation. In addition, third party monitoring can verify the results. Including clearly the topic of pellet loss in permissions and inspection is a guarantee for mutual understanding and attention. As we want to include the whole value chain, R&D can support and stimulate this broader scope.

Referring to the plastic recycler Aage Vestergaard Larsen (AVL) case in Denmark, measure 10.1 can be undertaken as part of normal business, for example as part of ISO 14001 procedures. This limits the extra costs.

Operation Clean Sweep is already established and in line with international standards (ISO). This makes the proposed voluntary commitment viable. There are also available technologies in place, but these have to be adjusted and developed according to local conditions.

According to our assessment, we believe that existing industry commitments, (10.1) on pellet losses in other countries, can also be an efficient measure in Norway and a basis for an overall plan to combat pellet losses. Increased monitoring (10.3) is meant as a punishment incentive and a control of the voluntary actions.

In detail we conclude:

- As a first measure, we propose that industry in Norway shall be asked to commit themselves according to international initiatives, such as Operation Clean Sweep. Such commitments shall comprise not only of losses from single plants, but also the losses from the value chain of pellets. In this way, by systematic work and reporting, industry themselves shall reduce the risk for losses. Currently both legislation/ inspections and initiatives from industry, often focus on emissions from single plants. However, transport and handling may very well be the weakest points in the value chain. In addition, this measure will bring better knowledge about losses and loss statistics. Similar to the commitments in Denmark, we presume that organizations, for example the Federation of Norwegian Industries and major companies within the value chain of plastics (producers of raw materials, plastic converters, compounders and recyclers) take part in the commitment. This as a typical Norwegian “dugnad”.
- As a second measure, according to the Pollution Control act, approvals and inspections at all plastic industry plants shall incorporate the issue of pellet loss at the plants. This includes an obligation to report any incidents. This measure should also include the whole value chain, if possible.
- As a third measure, we propose increased monitoring of pellet losses, close to plastic industry sites and water treatment plants.
- As a fourth measure, we propose more R&D, focusing on the whole value chain and logistics, inclusive mass balances and risk assessments.

Below, we have summarized the assessments. As can be seen from table 10.1, voluntary commitments obtain the highest score. The other measures can all strengthen the possible voluntary commitments.

Table 10-1 Evaluation scores for measures against plastic pellets loss

No	Evaluation of measures - microplastic pollution from: Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
		Tonnes reduction	Score 1-3	Cost per tonne Score 1-3	Available Techniques Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
10.1	Voluntary commitment from value chain		3	3	1,5	1,5	9
10.2	Include in plant permit and reporting obligation		2	3	1,5	1,5	8
10.3	Increased monitoring of pollution along coast		2	1	1	1	5
10.4	R&D, best practice on logistics value chain		2	1	1	1	5
TOTAL REDUCTION POTENTIAL		**450**	**Out of a total estimated Norwegian discharges at source of 8.400 tonnes of microplastics (2014)**				

10.2 Gross reduction potentials

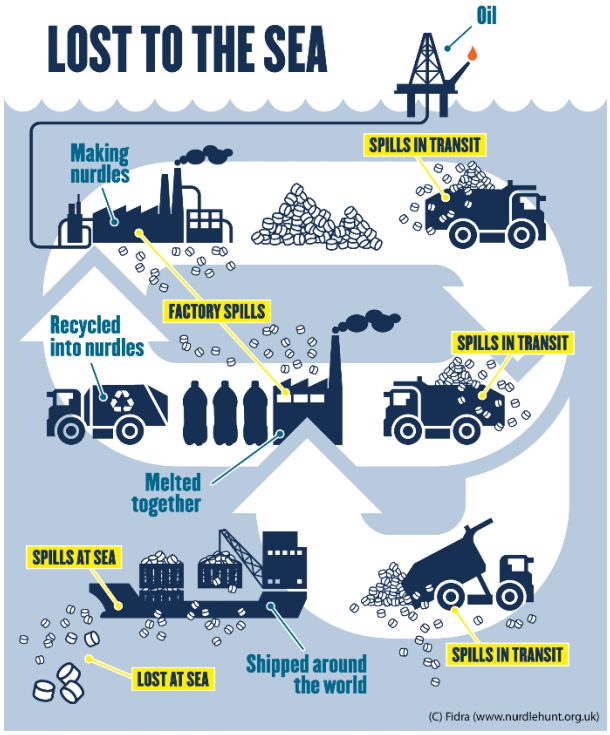
10.2.1 Summary of gross potentials from Mepex report 2014

We made the following estimates in the previous Mepex report:

- 250 tonnes from transport spill and
- 200 tonnes from production discharge, in total 450 tonnes.

The spills might take place, either at the plants or in transit. This is well- described in the illustration from Nurdle Free Oceans below.[32]

[32] http://nurdlehunt.org.uk/whats-the-problem/lost-at-sea.html



In practice, the logistics can be more complicated than illustrated, increasing the risk of pellet loss. For example, pellets from the plastic industry are often compounded before distributed to the plastic converters. At the compounders, the pellets are re-melted based on a mix of additives. These new pellets then comprise other substances different to the original polymers. Nevertheless, we regard all pellets as microplastics.

10.2.2 Adjustments and prognoses based on new knowledge

Below we discuss the estimates from our 2014 report, partly based on literature and partly based on information from industry, NGOs and observations from the coast.

From literature:

According to an article in 2015, the amount of pellets found in the ocean is now 75% lower than 30 years ago. These reductions may partly be a result of industry programmes[33]. We have not studied these international studies. However, as nurdles probably often sink, Mepex believes findings closer to the plants are the best indicators of pellet losses from plants.

[33] J.A. van Franeker and K.L. Law, 'Seabirds, gyres and global trends in plastic pollution', in *Environmental Pollution* 203, August 2015, pp. 89-96

The COWI report estimates the annual pellet loss in Denmark to 5-50 tonnes.[34] The COWI estimates are based on a survey among Danish converters in cooperation with the Danish Plastic Industry Federation.[35] Denmark has no raw material producers, as Norway has in Bamble and in Ålesund. In Norway, due to our size and transport logistics we very likely also have more transport/ handling than Denmark.

From industry directly:

According to Borealis in Austria, the plant outside Vienna experienced a major pellet loss in 2010. This accident related to a flood, reminding us about the possible impacts from climate change and flooding on pellet losses. Borealis says that 180-200 kg of pellets left the plant due to this loss and the pellets settled in a local river. Based on this accident, Borealis, and the Austrian EPA have taken a proactive approach to avoid and minimize further pellet losses.

In connection with this accident, the media referred to some estimates of daily emissions from this plant of 4.2 tonnes daily.[36] However, the average annual loss of microplastics at the Borealis plant in Schwechat was only 28 kg according a report from the Austrian EPA.

The report on microplastic in the environment from the Austrian Environment Agency, refers to a new study aimed at investigating plastic and microplastic particles in the flow of the Danube river in and out of Austria. Based on this method (not evaluated), the annual average of plastic discharges can be calculated. The report concluded:[37]

- 6-66 kg/day of microplastics, of which 10% attributed to industrial activities
- 7-161 kg/ day of all plastics, or less than 41 tonnes/ year.

Mepex has also been in contact with Plastics Europe representatives from the different Nordic countries, Borealis in Sweden, INEOS in Norway and Plastics Europe in Germany and the Netherlands. We could not obtain any further data on pellet losses.

Observations from the Coast

Mepex has documented different observations of possible pellet losses, partly from divers, diving off the coast close to the plants. The front page of this report illustrates pellet losses in Norway.

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[34] Lassen, C. et al. Microplastics- Occurrence, effects and sources of releases to the environment in Denmark. Published by The Danish Environmental Protection Agency, 2015.
[35] Fabiansen, Helle, Plastindustrien, Denmark, personal communication, telephone conference, 23 October 2015.
[36] Jochen Berrens, Borealis Polyolefine GmbH, Linz, personal communication, 02.12.15
[37] Hohenblum, Phillip et al, Plastic an microplastic in the environment, Environmental Agency Austria, 2015

Internationally, different campaigns also assess pellet losses. One example is the Great Nurdle Hunt, organized by the environmental charity Fidra in Scotland. They document all pellet findings in a map and present the results on the campaign pages[38]. Fidra also promotes 'Operation Clean Sweep'.

According to FFI, pellets have been found in Hawaii and Easter Island (large numbers)[39]

There are also studies in the Port of Antwerp where there are different plants.[40]

FFI and Dutch NGO Plastic Soup Foundation have registered pellets in Westerschelde area, not far from a plastic production plant in the Netherlands.[41]

As a conclusion, we will use the estimates on losses in Norway from 2014 as basis for this report. However, we underline that these estimates are very uncertain and we need further studies on the mass-flows of pellets.

10.2.3 Additional emission sources

The discussion on pellet loss often relates to resin producers and their plants. However, pellet loss should comprise the whole value chain from producer to converter, inclusive logistics and handling. By doing so, weak points in the chain can be identified. In addition, there are regranulate pellet losses from the recyclers to the converters using these recycled pellets. Including all these operators and the related logistics, the risk of pellet losses is much higher than losses at the plant of a resin producer. As can be seen below, legislation currently focuses on the plants and not the whole value chain.

[38] http://nurdlehunt.org.uk/take-part/nurdle-map.html
[39] http://voices.nationalgeographic.com/2015/10/15/ocean-pollution-race-for-water-odyssey-demonstrates-widespread-plastic-pollution/

[40] http://www.portofantwerp.com/sites/portofantwerp/files/POA-1370_Publiekskaart_EN-06102014_0.pdf
[41] www.plasticsouplab.org/hunting-for-plastic-nurdles-in-westerschelde/

10.3 Description of measures

In this chapter, we describe and assess the four measures against pellet loss. In the next chapter the measures will be evaluated.

10.3.1 Measure 10.1. Voluntary commitment from plastic value chain

Criteria	Comments
Background	The plastic industry, both as organizations and plants, has internationally made voluntary commitments to reduce their pellet loss. It is an opportunity for Norway to enhance and develop similar commitments.
Objective	Reduce pellet losses and the risk for pellet losses at plants and along the value chain in Norway.
Description	The Norwegian Environment Agency asks the plastic industry to commit themselves to 'Operation Clean Sweep' or similar voluntary initiatives. To formalize such a request, a voluntary agreement between Norwegian Environment Agency and The Federation of Norwegian Industries and/or the key plastic industry companies may be made. The commitment should comprise of resin producers, importers, converters and recyclers and with stress logistics and flood situations. As part of this commitment, industry should be asked to report actions and results in order to prevent losses within the value chain. Furthermore, industry should inform and document any losses by incidents. The commitment should also be a topic at the inspections. In order to implement these initiatives efficiently, companies often combine the commitments on pellet losses with similar programmes, like "Responsible Care" and ISO quality systems.
Possible incentives	Voluntary agreements is both an attractive and efficient way to obtain results for industry. PR for industry.
Reduction potential	450 tonnes
Cost estimates	Limited, as commitment fits into ISO certification. Filter investments etc. might be necessary. Involving all value chain is more complicated process.
Feasibility	Voluntary commitments are already in place, both internationally and in the Nordic region. Involving whole value chain is more complicated.

Link to other measures	Generic measure 5.2 and the three other measures in chapter 10.

The American industry has already taken some actions to reduce their pellet losses, e.g. Operation Clean Sweep:[42]

Operation Clean Sweep is an international program designed to prevent resin pellet, flakes and powder loss and help keep this material out of the marine environment. Every segment of the plastic industry has a role to play- including resin producers, transporters, bulk terminal operators and plastics processors-by implementing good housekeeping and pellet, flake, and powder containment practices. The goal: achieving zero pellet, flake, and powder loss.

The American Operation Clean Sweep web page includes a list of all global partners, who have committed themselves.

In Europe, Plastics Europe coordinates the same initiative.[43] However, as a first step, many producers have committed themselves to another, former Plastics Europe initiative called '*Zero Pellet Loss*'. *Zero Pellet loss* is the basis for internal actions to prevent pellet losses. *Operation Clean Sweep*, whereby the companies go public with their commitment, is the second step. Names of committed companies in Europe will probably soon be published. [44]

In the Nordic region, Denmark has been the most proactive country. The Danish Plastic Industry (Plastindustrien) has been very active on the issue of marine littering. As part of this, the Plastic Industry has established "Plastic free Oceans" (Project Plastfrit Hav) together with the two NGOs '*Plastic Change'* and '*The Ecological Council* '(Det Økologiske Råd) in 2014. The partners intend to launch different projects related to marine littering. The project has also obtained substantial funding. In Denmark, nine companies, so far, have committed themselves to *Operation Clean Sweep*[45]. Norway has obviously much to learn from the Danes.

The plastic recycler Aage Vestergaard Larsen (AVL) is one of these nine companies in Denmark. Based on this commitment, AVL is in the process of integrating this commitment to its quality and environmental management systems, e.g. ISO 9001 and 14001 (AVL is now preparing its first certification of ISO 9001 and 14001). This means that the focus on zero pellet loss is regarded as an important part of businesses quality and environmental management systems, rather than an additional burden. Based on internal investigations of the logistics, weak points in the value chain have been analysed and measures taken. For

[42] http://www.opcleansweep.org/default.aspx

[43] http://www.opcleansweep.eu/

[44] Ralph Schneider, PlasticsEurope, personal communication, telephone conference, 23 October 2015.

[45] www.plastindsutrien.dk

example, as a recycler, AVL receives several loads with scrap from the plastics industry daily that is often a mix consisting of many plastic products (e.g. pipes, other production waste, grinded material and pellets). When unloading such a mix, there is a high risk for pellet losses. Thus, AVL in dialogue with their suppliers, now implement better routines whereby different kinds of scrap have to be packed and transported separately.

As AVL pays their suppliers for all kinds of plastic scrap including pellets, reduced pellet loss is also good for business. The extra efforts related to the commitment is thus more or less covered higher efficiencies in their value chain. *Operation Clean Sweep* is thus a win- win: Good for the environment and good for business. Another overall conclusion is that work must take place onshore in order to reduce the amounts of microplastics in the oceans. AVL has stated it wants more cooperation on these issues among the Nordic countries. Better knowledge and transparency are part of such a cooperation.[46]

In Sweden Borealis in Stenungsund has their own "Let`s Catch the Pellets" programme.[47]

Borealis production in Stenungsund comprises both polyethylene(PE) and polypropylene (PP). In addition to Borealis, INEOS, INOVYN, AKZO and Perstorp have plants in the same area. Borealis has analysed and assessed risks of pellet losses, inclusive of very fine particles/powder and taken measures to reduce these risks. Measures include new filters and internal campaigns, similar to the Zero Pellet loss programme. Loading trucks is regarded by the company as a weak point in the chain (probably this is a weak point for all plastic industry). Borealis has an obligation to report losses, but no incidents are reported so far. Incidents outside the plant are not included in these reporting routines.

Pellet loss is a topic at the inspections from local authorities, e.g. Länsstyrelsen, Västre Gøtaland and also a topic for the plant operation licence from Miljø –og markdomstolen, Vännersborg.

In Norway INEOS has an internal Zero Pellet Loss programme at each plant in Bamble. No information about the programme is available. For example, no information about the measures in detail nor information on any losses are available. INEOS states that they are not aware of any losses from their plants in Bumble.[48] However, the issue of pellet losses is already on the agenda at inspections.[49] INEOS also state that they are not aware of any losses from their PVC plant in Bumble[50]. However, some of this information is contradictory. For example, in the media INEOS admits that some microplastic pollution is stemming from their plants.[51]

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[46] Franz Cuculiza, CEO of AVL, personal communication, 15.10.15
[47] Marie Louise Johansson, Borealis, Stenungsund, personal communication, 2 November 2015
[48] Dag Berstad, INEOS Norway, personal communication, 07.10.15
[49] Marit Jerpeset, Norwegian Environment Agency, personal communication 23 October 2015.
[50] Dag Berstad, INEOS Norway, personal communication, 07.10.15
[51] https://www.ineos.no/index.php/nyhetsarkiv/111-artikkel-i-telemarksavisa-pellets-i-sjoen

Borealis, partly based on the accident in Vienna, has taken a proactive approach and takes part in both Zero Pellet Loss and the Operation Clean Sweep. We expect that Borealis and other international companies, soon will go public with their commitments.

In Norway, Brødrene Sunde is a leading PS resin producer, no detailed figures were obtained on pellet losses in 2014.

10.3.2 Measure 10.2. Include the microplastic issue as part of plant permit and reporting obligation

Criteria	Comments
Background	Pellet losses are observed outside the plants of plastic manufacturers in Norway (and in other countries). Legal clarification, more attention and transparency can be a good basis for reduced losses and reduced risks for such losses. Plant permits and reporting obligations can be more specific on the issue of microplastics.
Objective	As part of a legal clarification the microplastic issue shall be included in plant permits and reporting obligations. The responsibility shall comprise all value chain of pellets.
Description	Approvals and inspections at all plastic industry plants shall comprise the issue of pellet loss and comprise the value chain for the pellets produced. This measure can be based on an obligation in The Norwegian Pollution Act, §7. However, this paragraph covers only emissions from the specific plant, not the whole value chain, while measure 10.1 Voluntary commitments can include the logistics as well. According to the regulations, the company shall report any accidents related to pellet losses, as illegal pollution, as part of their annual declaration/ report to the Agency. Measure 10.1 Voluntary commitments can include further obligations, for example information to the local community. Measure 10.2 is already based on existing law. However, the legal obligation is more limited than a possible voluntary agreement.
Possible incentives	Easy to take clear obligations into account. Reporting obligations as basis for transparency and public awareness. Legal basis enhance the job to include the whole value chain.
Reduction potential	450 tonnes
Cost estimates	Limited, as commitment fits into ISO certification. Filter investments etc. might be necessary. Involving all value chain is more complicated process.

Feasibility	The issue is probably already on the agenda, but possibly limited to the plant itself. Involving whole value chain might be more complicated from a legal perspective.
Link to other measures	Generic measure 5.3 Legislative clarification The three other measures in chapter 10.

10.3.3 Measure 10.3. Increased monitoring close to industrial plants

Criteria	Comments
Background	Pellet losses are observed outside the plants of plastic manufacturers in Norway (and in other countries). Pellets can also be found end of pipe from waste water treatment plants and rivers. It is a need to monitor the pollution situation in general, identify pollution sources and follow up voluntary commitments (10.1), plant permits and reporting obligations (10.2) and also similar measures related to waste water treatment plants (14.1). As part of a consistent quality and control system it is a need for increased monitoring close to industrial plants (as a hot spot for discharges).
Objective	Identify pollution sources, accidents and the results of pellet loss reduction programmes. Objective can also be to identify former losses and research on fate and degradation in sediments.
Description	Increase monitoring of pellet losses, close to plastic industry sites and water treatment plants. This can be done on regular basis, professionally, or as part of a R&D programme. This measure can also be done as part of divers' research, trash tagging and clean up campaigns.
Possible incentives	This control mechanism can be used a s a stick for better performance within industry.
Reduction potential	200 tonnes
Cost estimates	Probably rather expensive, but costs can be reduced/ shared: • Can be tested out as R&D, also related to other sources, e.g. waste water treatment plant and rivers. • Can be part of voluntary divers' research, trash tagging and clean up

	campaigns.
Feasibility	Technology and competence needed. R&D Institutes (Bergen) already interested to monitor pellets/ microplastics in sediments.
Link to other measures	The three other measures in chapter 10. Monitoring can alternatively be integrated in measure 10.1. Voluntary commitments and 10.2 Plant permits and reporting obligations.

10.3.4 Measure 10.4. R&D, best practice on logistics in the plastic value chain

Criteria	Comments
Background	Pellet loss is one major pollution source. More R&D can help to find the weak points in the value chain and develop best practice in order to reduce risks and losses.
Objective	Develop best practice in order to reduce risks and losses.
Description	R&D focusing on best practice related to pellet handling and logistics. This also comprise competence, routines, attitudes. This can be supported by studies on mass-flow analyses, logistics and risk assessments. R&D can be organized as Norwegian projects as well as EU programmes.
Possible incentives	Financing of R&D
Reduction potential	250 tonnes (logistics)
Cost estimates	Medium. Can also learn from voluntary initiatives internationally. Can also join forces internationally.
Feasibility	High attention on microplastics including pellet losses might enhance financing of such R&D programmes. Based on commitments (10.1) and legal obligations (10.2) industry may be interested to finance such R&D.
Link to other measures	The three other measures in chapter 10.

11 Assessment of reduction potentials and measures for waste and recycling

11.1 Conclusions and summary

There is considerable uncertainty in the estimates of emissions from the waste management industry. Further studies are needed.

In order to increase knowledge, estimate the risks and improve technology, we have assessed three measures. These measure will not directly reduce discharges, but will be a good basis for further actions, if needed.

Table 11-1 Evaluation scores for measures against waste related microplastics

No	Evaluation of measures - microplastic pollution from: Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
		Tonnes reduction	Score 1-3	Cost per tonne Score 1-3	Available Techniques Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
11.1	Monitoring discharges	**0**	1	1	1.5	0.5	4
11.2	Investigation and risk assessments	**0**	1	1	1.5	0.5	4
11.3	Evaluate and develop technology	**0**	1	1	1.5	0.5	4
TOTAL REDUCTION POTENTIAL			**Out of a total estimated Norwegian discharges at source of 8.400 tonnes of microplastics (2014)**				

11.2 Gross reduction potentials

11.2.1 Summary of gross potentials from Mepex report 2014

The Mepex report (table 8.1 s 82) gives the following estimate for Norwegian discharges of microplastic to the sea from waste and recycling activities:

Waste shredding	Plastics recycling	**n.a.**		*drain,sludge, air*	PS, PA
	Illegal dumping, paint	**100**	1.2	*soil, sea*	
	Landfills	**n.a.**		*air, water*	
	Biowaste	**336**	2.4	*soil, water*	
	Paper recycle	**60**	1.2	*water*	Latex, PE, S
	WEE and ELW	**10**	0.1	*air, water*	ABS and more

The figures of microplastic from bio-waste treatment do not include discharges from sewage sludge treated in biogas and compost plants.

11.2.2 Adjustments and prognoses based on new knowledge

We have no substantial new information to justify adjustments in the estimated discharges. However, there are good reasons to emphasize the considerable uncertainty in the estimates. The following paragraphs gives details about this.

11.2.2.1 Paper recycling

The estimated discharges to the sea of 60 tonnes of microplastic from the paper recycling industry has been discussed with relevant staff at the Norske Skog plant in Skogn[52]. According to their information, the discharge of paper fibres is 200 tonnes per year where about 60 tonnes per year (29 %) comes from recycled paper. The Mepex 2014 worst-case estimate of 60 tonnes of microplastic equals the paper fibre discharge. It seems like this is an overestimate but there are no knowledge to give a more accurate estimate. The discharge cleansing at the plant is according to BAT 2018. Discharge of microplastic from the plant has not been measured. Discharge of microplastic from paper recycling has not been in focus neither in the industry nor by the environment authorities.

Eunomia 2015[53] refers to the estimates in Mepex 2014 without going into the basis for the calculations. They conclude that it is difficult to upscale Mepex figures to European level and recommend sampling of the effluent from paper recycling along with sampling of the input paper types to better understand of the extent to which discharges from paper recycling may be an issue.

11.2.2.2 Metal shredding

Mepex 2014 estimates discharge of 10 tonnes of microplastic to sea from metal shredders. This figure was reviewed by an expert[54] from metal shredding and is considered as reasonable but knowledge of micro-plastics in discharges is deficient and estimates are therefore uncertain.

Eunomia 2015[55] gives a short description of possible microplastic discharges from End of Life Vehicles (ELV) shredding without giving any estimate. Based on the total amount of residuals from the shredders they conclude that there is potentially a substantial discharge of microplastic that may need to be addressed.

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[52] 16.11.2015 - Personal communication with Per Nonstad. HMS officer in Norske Skog, Skogn

[53] Simon Hann, Eunomia. 5 September 2015, Study to support the development of measures to combat a range of marine litter sources. WP 2: Preliminary scoping exercise of options to achieve a phase-out or ban of microplastics in cosmetic products. Report for DG Environment, European Commission.

[54] 16.11.2015 – Personal communication and email with Geir Allum Sørensen, manager at NG Fredrikstad.

[55] Simon Hann, Eunomia. 5 September 2015, Study to support the development of measures to combat a range of marine litter sources. WP 2: Preliminary scoping exercise of options to achieve a phase-out or ban of microplastics in cosmetic products. Report for DG Environment, European Commission.

11.2.2.3 Plastic recycling

Recycling of plastic can potentially give rise to discharges of micro plastic both in relation to dry and especially wet sorting and washing. However, this issue is not presented nor are there any other findings that could verify or quantify this. Most of the plastic collected for recycling in Norway is exported. It is therefore likely that most of the discharges occur overseas.

11.2.2.4 Landfills

Landfills consists of large amounts of plastic waste representing an enormous potential for discharges. According to landfill experts, there are strong indications of some discharges based on analysis of plastic related substances in landfill leachate. Nonetheless, we have not been able to verify or quantify the discharges any further. Even less is known about the long and very long term consequences of these enormous plastic deposits.

Landfilling of plastic waste has more or less ceased after strong restrictions on landfilling of biodegradable waste put in place about 10 years ago. Leachates are monitored for a long time after termination of the landfill, but in the very long-term perspective, this may not be sufficient.

Landfill mining is potentially a growing business in the future, based on growing interest for use of landfill areas combined with interest for the resources in landfills. Such activities can possibly create large discharges of micro plastic if not carried out in a safeguarded manner.

We can expect wet, stormy and unstable weather in the future giving rise to floods, landslides and other events disrupting the stability in the landfills. There is great potential for discharges if landfills lose their stability considering the large amounts of plastic materials landfilled.

11.2.2.5 Illegal dumping

The scale of illegal waste dumping and landfilling is by its very nature, unknown. Although the volume is small, the potential for pollution can be large because these spots are not protected against exposure for wind and water.

11.3 Description and assessment of measures

In this section, we describe and assess three different measures:

11.3.1 Measure 11.1. Monitoring discharges

Criteria	Comments
Background	Knowledge of discharges of microplastics from landfills and recycling plants, in particular, is lacking. There are methods and technology to measure such discharges. Better knowledge is necessary as a basis for decisions on discharge reduction and

	development of technology.
Objective	Better knowledge of discharge.
Description	Investigate the discharges of micro plastic from selected industries.
Possible incentives	Financed or ordered by the pollution authorities.
Reduction potential	The measure will not in itself lead to discharge reductions but is necessary as a basis for action. In addition, the measure could create a greater awareness, which in turn can lead to discharge reductions, possibly also based on new legal requirements.
Cost estimates	1 000 000 NOK
Feasibility	Initiatives from Environmental authorities, certifications and quality standards
Link to other measures	All measures in this section are closely linked together

11.3.2 Measure 11.2. Investigation and risk assessment of landfills

Criteria	Comments
Background	Landfills contain enormous amounts of plastic waste which in a long-term perspective can give rise to large discharges of micro plastic. Our managements plans and regulations don't cover this long-term risk. Better knowledge of the present situation regarding discharges of microplastic from landfills will be important in evaluating risk.
Objective	Better knowledge of future risk.
Description	Knowledge-based analysis and evaluation of risk for future discharges from landfills
Possible incentives	Financed or conducted by the pollution authority.
Reduction potential	The measure will not in itself lead to discharge reductions but is necessary as a basis for action.
Cost estimates	500 000 NOK
Feasibility	Linked to any flood preparedness projects and urban mining
Link to other measures	All measures in this section are closely linked together. Also linked to the generic measure 5.7 Flood preparedness

11.3.3 Measure 11.3. Evaluate and develop technology.

Criteria	Comments
Background	Our knowledge indicates large possible discharges from several sources in the waste and recycling industry like paper recycling and landfills. Most of these industries are regulated by permits. We do not know the best technologies for discharge reduction. Possibly there are some interfaces towards technology for cleansing sewage discharge. The costs are probably very high for reducing discharges by new cleansing technology. Research into technologies is necessary before any investment should be made.
Objective	Decision basis for investment in new technology.
Description	Research activities for evaluation and development of discharge reduction in landfill leachate and other industrial water discharges.
Possible incentives	The measure is related to quality standards
Reduction potential	The measure will not in itself lead to discharge reductions but is prerequisite for future reductions.
Cost estimates	1 000 000
Feasibility	Innovation programs
Link to other measures	All measures in this section are closely linked together

12 Assessment of other reduction potentials and measures within industry and offshore activities

12.1 Conclusions and summary

In this chapter of other reduction potentials, we will limit our focus on offshore activities. Other industrial sources are not discussed further in this report or are partly discussed elsewhere. We specifically focus on:

- Industrial washing, incl. fish farm nets and public laundries, however public laundry considerations are closely related to chapter 8 on textiles.
- Industrial detergents, see chapter 9 cosmetics and detergents.
- Industrial waxes, see discussion on definitions in chapter 4.1.
- Plastic grindings and cuttings from industry, see chapter 11 on waste and recycling.

According to our brief research within the oil industry, we assess the micro plastic discharges to be minor. Nevertheless, based on experience from other sources such as paint and tyres, we suggest further efforts to verify this conclusion. We also propose measures to develop knowledge and strengthen regulations and control mechanism. As a key measure we propose 12.4- Regulatory binding definitions of microplastic.

Table 12-1 Evaluation scores for measures against offshore microplastics discharges

No	Evaluation of measures - microplastic pollution from: Offshore and other industry Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
		Tonnes reduction	Score 1-3	Cost per tonne Score 1-3	Available Techniques Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
12.1	Further investigation and analysis	**0**	1	1	1.5	1	4.5
12.2	Environment classification	**0**	1	1	1.5	1	4.5
12.3	Reporting obligation	**0**	1	1	1.5	1	4.5
12.4	Regulatory binding definitions of microplastics	**0**	1	1	1.5	1.5	5
	TOTAL REDUCTION POTENTIAL	**0**	**Out of a total estimated Norwegian discharges at source of 8.400 tonnes of microplastics (2014)**				

12.2 Gross reduction potentials

12.2.1 Summary of gross potentials from Mepex report 2014

The Mepex report describes possible discharges of microplastics from offshore oil drilling and oil production without giving estimates of amounts. However, such discharges are outlined as knowledge gaps in the report.

12.2.2 Adjustments and prognoses based on new knowledge

Discharge from oil production and exploration is strictly regulated in Norway according to national regulations[56] based on the OSPAR convention. All operations are subject to permission from the authorities where emissions are regulated. The operators are obliged to report their use and emissions of chemicals and substances to authorities on an annual basis.

The regulation of discharges to the sea is based on classification of the substance's inherent ecotoxicological properties. Substances are classified in four different categories of increasing severity (green, yellow, red and black) where emissions of the potentially most harmful substances are strictly regulated and monitored. Substance classification is based on priority lists (national and OSPAR, REACH Candidate List) and properties regarding biodegradability, bioaccumulation potential, toxicity and harmfulness to reproductive systems or in a mutagenic.

Microplastics should, in principle, be classified as 'red' due to a low degree of biodegradability. If so, this would involve strict restrictions on discharges of substances containing micro plastic. The newly revised regulation explicitly states that discharges of plastic will not be permitted.

Discharges from offshore oil exploration can broadly be divided in three groups; production, drilling and diffuse discharges.

- Discharges from production are mainly a result of the separation process (water, oil, gas from the oil well) where the water with content of added chemicals in many cases is allowed to be discharged into the sea, after cleaning of its oil content below 30 ppm. We have no knowledge of use of microplastic or polymers in these processes.
- In the drilling process different chemicals are used to provide hydrostatic pressure in the well, cooling and lubrication of the drill bit, suspension and removal of drill cuttings and to avoid formation of damage and corrosion. The water based fluids which are classified as green or yellow are generally allowed to be discharged into the sea. Discharges of oil based fluids or chemicals with potential environmental risk is usually not permitted. Microplastic and polymer is among the substances that are

[56] Aktivitetsforskriften. Regulations relating to conducting petroleum activities. http://www.psa.no/activities/category399.html

used in drilling fluids and cement. In 2015 the Norwegian Environment Agency ordered all operators to report their use and discharges of substances containing microplastic of polymers. Discharges of microplastic are minor according to the reports (ca 2 tonnes), but many of the operators point out that unclear definition of microplastic/microbead makes is difficult to give accurate reports. Some of the substances used in the industry are perceived as not included in the definition. Discharges may therefore be larger than the amount reported to the Agency.

- Diffuse discharges are all other discharges related to oil and gas exploration, including transport, maintenance of installations, avoidance of emergency etc. The discharges of microplastic from such activities are assumed to be low.

12.3 Description and assessment of measures

In this section, we describe and assess different measures to reduce the amount of microplastic discharges from offshore activities.

We have described four measure below, the last measure 12.4 – A clear regulatory binding definition, can be regarded as a generic measure. All the measures are linked together.

12.3.1 Measure 12.1. Further investigation and analysis of use and discharges

Criteria	Comments
Background	Mepex has observed that reporting to the Norwegian Environment Agency reveals a lack of knowledge and awareness in the offshore industry concerning use and discharges of microplastics. This observation may be related to an unclear definition of microplastics. Based on the substantial and systematic knowledge of use and discharges of substances in general, it should not be very difficult to establish a better knowledge of microplastic used in products.
Objective	The aim of the measure is to provide better and more reliable information on the use and possible discharges of substances containing micro plastic in the oil industry.
Description	Research and investigation.
Possible incentives	Incentives or orders from the pollution control authorities to operators who have discharge permit.
Reduction potential	The measure will not in itself lead to discharge reductions but is still required to understand the situation within this industry. In addition, the measure could create a greater awareness, which in turn can lead to discharge reductions.

Cost estimates	Ca 500 000 NOK ("guestimate" - not confirmed)
Feasibility	The measure can easily be carried out since we already have a lot of knowledge about the use of the individual substances in the industry and since there are competent research institutions that could carry it out.
Link to other measures	All measures in this section are closely linked together

12.3.2 Measure 12.2. Evaluate the environment classification of substances

Criteria	Comments
Background	The classification of the substances regarding environmental damage is not necessarily intended for substances like microplastic where the environmental effects can be complex and long term. Current practices indicate some challenges regarding classification of degradability of substances containing micro plastic. Micro plastics should in principle be characterized as red due to a low degree of biodegradability. If so, this would involve strict restrictions/justifications on discharges of substances containing microplastics.
Objective	Consistent practice in accordance with the regulations for environmental classification of substances containing micro plastics.
Description	Review of practices and regulations for characterization
Possible incentives	Incentives or orders from the pollution control authorities to operators who have a discharge permit.
Reduction potential	The measure in itself will not lead to discharge reductions, but is required to monitor the situation. In addition, the measure could create an obligation or at least greater awareness and pressure for substitution which in turn can lead to discharge reductions.
Cost estimates	Ca 1 000 000 NOK ("guestimate" - not confirmed)
Feasibility	The measure can easily be carried out.
Link to other measures	All measures in this section are closely linked together

12.3.3 Measure 12.3. Reporting obligation

Criteria	Comments
Background	Operators are obliged to report their use and discharges of chemicals to authorities on an annual basis. Currently they are not given specific reporting obligations for substances containing microplastic.
Objective	Introduce reporting requirements regarding microplastic use and discharges in discharge permits for the oil industry.
Description	Reporting obligations.
Possible incentives	Change or extension of current permissions.
Reduction potential	The measure in itself will not lead to discharge reductions but is still required to monitor the situation. In addition, the measure could create a greater awareness which in turn can lead to discharge reductions.
Cost estimates	Ca 5 000 000 NOK ("guestimate" - not confirmed)
Feasibility	As the permissions give detailed reporting obligations regarding use and discharges it should not be very difficult to introduce this.
Link to other measures	All measures in this section are closely linked together

12.3.4 Measure 12.4. Establish a regulatory/binding clear definition of microplastic

Criteria	Comments
Background	According to reports to environmental authorities from the operators, there is uncertainty related to the definition of micro plastics and which substances are covered by the definition and which are not. Of the substances used in the oil industry, there are several that have small particle size microplastics that may fall outside the definition.
Objective	Avoid misunderstanding related to definitions
Description	Clarification of definition
Possible incentives	An international initiative through OSPAR in order to establish regulatory or binding definition of microplastics.
Reduction potential	The measure will not directly lead to discharge reductions, but it may do in combination with the others if it turns out that things being dumped now may not be permitted to be dumped in the

	future
Cost estimates	Ca 500 000 NOK (“guestimate” - not confirmed)
Feasibility	Maybe difficult and time consuming since it has to be coordinated internationally
Link to other measures	Measures in this section are closely linked. 5.3 Legislative clarificat.

13 Assessment of reduction potentials and measures for additional sources

Photo: Rubber granulate is added every year to artificial sport turfs, so where does it end up?

13.1 Conclusions and summary

In addition to primary sources documented in the Mepex report from 2014, there might be several other relevant sources to follow up.

In this chapter, we will focus on the following sources:

- Discharge of microplastics from artificial football pitches, inclusive of some information about other applications for other sports and playgrounds.

In the former Mepex report, we categorized emissions of rubber granulate and artificial grass from football fields as “other commercial uses” of designed microplastics. However, the report included no estimates. At that time, we had the understanding that any loss from the fields was collected.

In Norway, based on data from Sweden, we roughly estimate an annual loss to the environment of 3.000 tonnes of granulates from football fields annually. Assumed at a 50% share of plastics, the same assumption as for tyres, the total is 1.500 tonnes of plastics.[57] We recommend further studies on these emissions, both the total emissions from source and on the amounts ending up in waterways.

In addition to granules, there are losses of artificial grass from the same fields. Furthermore, there is loss of granulates from other sporting and recreational facilities, such as playgrounds, athletic tracks and similar areas. There are some rough estimates on these discharges in the Danish study.[58] In Norway, some artificial pitches are reused for other purposes, including shooting galleries, horse tracks and even reindeer farms. However, these rough estimates and new sources all need further investigations.

There are also discussions on the environmental impacts from these granules, considering hazardous substances and metals such as zinc. In this report, we do not elaborate on these important aspects discussed both in Sweden, Norway, UK and USA.[59] According to the Norwegian Football Association, stricter quality standards to new granulates are in discussion. The Ministry of Culture is involved in these discussions. The Norwegian take-back scheme for tyres, Dekkretur and its owners are also working for better standards.

In order to reduce the microplastic pollution from football pitches, we have described and assessed four specific measures.

As an overall prevention measure, in 13.1 we have proposed a promotion of natural football pitches. As the artificial football pitches have many advantages and practice can be improved, we do not recommend a blanket phase out the artificial pitches. Instead, we have assessed three relevant practical measures, 13.2-13.4, related to existing and planned pitches, illustrating the fact that both type of construction and good maintenance routines can make a difference. All measures need more investigation.

In order to secure safe routines at all pitches in Norway, we also propose a generic measure: A voluntary commitment from industry on certified operations and a take-back for reuse and recycling.[60] The take back obligation should comprise both the granules and the end of life turfs. We believe that this take-back obligation is in line with the new EU Circular Economy Package and further EU instruments related to both microplastics and recycling. The Norwegian Football Association (NFF) is already committed to these issues and should play a

[57] See discussion in chapter 4.1. Shall we just count the polymer part or the total weight of the granules?
[58] Lassen, C. et al. Microplastics- Occurrence, effects and sources of releases to the environment in Denmark. Published by The Danish Environmental Protection Agency, 2015.
[59] Dagbladet, article 16 February 2016, 34 football keepers with cancer
[60] Read more about this generic measure number 5.4

key role for any of these measures.[61] In addition, we believe that organizations financing these artificial turfs shall be included as a responsible partner to secure high environmental standards.[62] As the Ministry of Culture is currently playing a central role on financing and requirements for new turf, the Ministry should also be actively involved.

Table 13-1 Evaluation scores for measures against microplastics from artificial soccer turfs

No	Evaluation of measures - microplastic pollution from: Soccer turfs Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
				Cost per tonne	Available Techniques	Existing initiatives	Sum
		Tonnes reduction	Score 1-3	Score 1-3	Score 0,5-1,5	Score 0,5-1,5	Score 3-9
13.1	Promote natural football pitches	n.a	1	2	1.5	0.5	5
13.2	Prevention by better construction of pitches, including retention system, indoor pitches and use of alternative materials	n.a	2	2	*1.5*	1.5	7
13.3	Procedures for safe sweeping and snow removal	n.a	2	2	1.5	1.0	6.5
13.4	Safe storage for reuse and take back solutions	n.a	2	2	1.5	1.0	6.5
	TOTAL REDUCTION POTENTIAL	n.a	**Out of a total estimated Norwegian discharges at source of 8400 tonnes of microplastics (2014)**				

[61] Norwegian Football Association, Høringsutkast Miljøaspekter ved kunstgress, includes guidelines and requirements, no date

[62] Norsk Tipping is a key contributor to financing, but decisions and environmental requirements are set and followed up by the Ministry of Culture. See general requirements in Attachement 10 of Bestemmelser til tilskudd til anlegg for idrett og fysisk aktivitet- 2015

13.2 Gross reduction potentials

13.2.1 Gross reduction potentials: artificial football turfs

According to the Norwegian Environment Agency, there are about 130.000 tonnes rubber granulate in use in Norway. Most of these granulates are based on used tyres. About 76.000 tonnes from such tyres are now in use on artificial football pitches.[63] In Norway there are currently over 1000 artificial soccer turfs (64 x 100 meters). In addition, there are about 2.500 mini turfs and 300-400 pitches of 60 x 40 meters. In Norway, there were just 100 artificial pitches in 2001. The numbers are still increasing and we have to expect an increase of turfs that shall be removed and replaced the coming years. One reason for this success, is that a natural football field is used 400 hours in average per year, whereas an artificial turf is used for 2.200 hours. Replacement of artificial pitches can be financed (from Ministry of Culture) after 10 years, based on well managed maintenance.[64]

According to another source in Norway,[65] the estimates of rubber granulate are higher: in total 95.600 tonnes in use, of which 85.000 tonnes in football fields, 6.500 tonnes in tracks, 3.400 tonnes in playgrounds and 1.700 tonnes in rubber asphalt in playgrounds. It is reported that huge amounts of granulates are stored close to the football fields. As many football teams have limited economic resources, it is a general concern that both granules and artificial grass are not well maintained, as many football fields require replacement during the next few years.[66]

According to the Norwegian Football Association, snow removal is a critical operation. There are good technologies in place both for removal and storage. However, these guidelines are followed by a minority of the clubs. The guidelines include a method to store the removed snow (including removed granules) on a plastic nonwoven cover for storage for granules to be reused next season.

In Sweden, there were 680 outdoor artificial football fields in 2011. The ambition is to have at least one arena in every municipality. The fillings consist of rubber granulates, either black SBR (Styrene-Butadiene Rubber) - a synthetic rubber from tyres, TPE rubber (thermoplastic elastomer) or green EPDM (Ethylene Propylene Diene Monomer)-a synthetic virgin rubber. The Swedish Football Association recommends the latter material. However, SBR is by far the cheapest solution. According to the Norwegian Football Association, SBR contributes by about 90% of the granules in Norway, SBR has also very good properties for use on pitches.

It is assumed that a normal football field contains 75-125 tonnes of rubber granulates and due to losses, about 10% shall be added every year, e.g. 7.5-12 tonnes. Snow and salting

[63] Norwegian Environment Agency, Article on web page: Resirkulert gummigranulat kan brukast trygt, September 2012
[64] Myrhvold, Ole, Norwegian Football association, personal communication on 28 January 2016
[65] Rolf Tore Ottesen et. Al, Gamle Bildekk på avveie, article in Adressa, 17.01.13
[66] Rolf Tore Ottesen et. Al, Gamle Bildekk på avveie, article in Adressa, 17.01.13

increase the need for annual refilling. As football pitches come in different sizes, the Swedish average loss per turf annually is estimated at 6 tonnes, of which 3 tonnes (50%) is lost to nature. [67]

Based on these Swedish rough estimates, the losses in Norway amount to above 3.000 tonnes of granulate each year, which is a volume previously not properly accounted for. Counted as synthetic rubber polymer (about 50%) this is 1.500 tonnes per year, making it one of the largest single discharge of microplastics in Norway, estimated at the source.

The Swedish estimate for annual loss to water (*i.e.* by run-off) is around 70 kg per year from each turf on average. For Norway this would amount to above 70 tonnes and hence a significant microplastics source to the sea and waterways. The estimate of the share ending up in waterways, is based on Danish methodology and assumptions in the COWI study, where about 90% of the losses are captured in the sewage treatment plants. This assumption needs further discussions, both in Norway and Sweden. Due to a rougher climate and poor waste water solutions, losses to waterways may be much higher in Norway. The pictures below illustrates poor management.

Photos: Trondheim city authorities has documented how turf owners allow rubber granulate to spread during snow removal and runoff, here directly to the nearby river where it has been found in fish stomachs. [68]

13.2.2 Additional emission sources

In addition to the granules, there are losses of artificial grass from football pitches. According to the Danish study, these emissions increase the emission amounts by about 20%. Due to some reuse of the grass turfs in Norway, horse tracks etc., the figures may be even higher.

[67] Frida Åberg, personal communication/ estimates. Swedish Agency for Marine and Water management (Havs og- vattenmyndighetene), Sweden, 2015

[68] Ottesen, R.T. et al. Spredning av miljøskadelige stoffer fra kunstgressbaner, article, no date

Furthermore, there is loss of granulates from other sources, such as playgrounds, athletic tracks and similar applications. According to the Danish study, these emissions increase the amounts from football pitches by about 100%.[69] These rough estimates all need further investigations.

13.3 Description and selection of measures

In this chapter, we have below described and assessed four specific measures.

In addition, a voluntary commitment from industry is very relevant. For more information, see the generic measure 5.4 in chapter 5. We believe that a voluntary agreement from the suppliers of both granules and artificial grass turfs (*i.e.* key players in the upstream value chain) can be an efficient solution. Norsk Dekkretur, the national take back system for tyres, is part of this value chain. Together with the operator Ragn Sells, 57.000 tonnes of tyres were collected in 2015, football pitches is a key market for granules from tyres. Such a commitment can be combined with existing (and improved) requirements, both to new pitches and to maintenance of existing ones, as well as stricter standards for the granulates. A voluntary commitment can also be strengthened by defined roles for the Ministry of Culture and the Norwegian Football Association. We believe this commitment should comprise of reuse, recycling and safe disposal too, including recycling of the artificial grass. There is already technology in place for treatment of the grass, for example, a Danish recycler promises a high recycling rate at its new plant.[70] Other operators are also active in this field.

13.3.1 Measure 13.1. Promote natural football pitches

Criteria	Comments
Background	The growth in the numbers of artificial turfs has been immense in Norway the latest years: 100 turfs in 2001, now we have more than 1.000 full size turfs. The rationale behind artificial soccer turfs is to stimulate football and extend the season despite the difficult Norwegian climate that lowers the grass quality and player comfort in the winter season. The main purpose of most soccer pitches are as training fields for youth, children and amateur players.

[69] Lassen, C. et al. Microplastics- Occurence, effects and sources of releases to the environment in Denmark. Published by The Danish Environmental Protection Agency, 2015.
[70] http://www.genan.eu/home-1.aspx

Objective	The aims of this measure is to promote and support natural fields as well and avoid artificial soccer turfs near waterways or at places where a natural turf is a good alternative.
Description	Financial support to natural turfs. Restriction to artificial turfs.
Possible incentives	The Norwegian funding system for public cofinancing of soccer fields (Tippemidler) should not discriminate against natural football turfs. Furthermore, strict requirements to plants, maintenance and recycling of artificial turfs will be a negative incentive for artificial turfs, regardless of some financing.
Reduction potential	Not assessed
Cost estimates	Moderate- Precautionary actions are in general cheaper than clean up, for society.
Feasibility	This is mainly a question of balancing different interests: Environment and costs vs sports purpose.
Link to other measures	Generic measure 5.4 Restrictions on the use of microplastics

13.3.2 Measure 13.2. Better construction to avoid particle escape

Criteria	Comments
Background	During snow removal, passive transport by runoff from heavy rain, and walking traffic, the rubber granulate is moved out of the football field area. There are already requirements from the Ministry of Culture to new football turfs. There are also currently discussions on how these requirements can be strengthened. As far as we know, the microplastic issue and recycling are so far not taken into consideration.
Objective	The aim of this measure is to avoid rubber granulates from escaping the artificial turf areas by better construction of the plant, inclusive of a safe location.
Description	Develop existing requirements, followed up by tests, certification and audits in order to reduce the risk of microplastic discharges. This includes all measures to reduce the risk for losses from a new pitches, including room for safe storage facilities.

	Promote indoor facilities. Promote the development of natural alternative materials to SBR, incl R&D.
Possible incentives	The Norwegian funding system for public cofinancing of soccer fields (Tippemidler) should develop further incentives and requirements to reduce the risk of any losses.
Reduction potential	Not assessed.
Cost estimates	This is a moderate to high cost measure.
Feasibility	If the turf is located near a waterway this measure is strictly necessary. At other locations, good procedures for safe sweeping and safe snow removal, might be more relevant.
Link to other measures	Measure 13.3 and 13.4 below and generic measure 5.7 –flood preparedness

13.3.3 Measure 13.3. Procedures for safe sweeping and snow removal

Criteria	Comments
Background	Good sweeping machines currently exist that are able to collect most particles and also sort them for reuse. However, just a minority of the clubs use these machines today.
Objective	The aim of this measure is to make sure rubber granulates are not actively, or by negligence during maintenance, transported to the environment.
Description	Sweeping machines should be available and compulsory to use for all football turf owners. Machines could be shared among clubs to reduce investment costs, and could also be owned by the local municipality.
Possible incentives	These costs should be included in the construction and maintenance budget, and funds granted also from the public funding system.
Reduction potential	Not assessed
Cost estimates	Moderate costs
Feasibility	Reuse of granulates can save costs.
Link to other measures	Measure 13.2 and 13.4

13.3.4 Measure 13.4. Safe Storage for granulate reuse and take back/waste solutions

Criteria	Comments
Background	There are good solutions in place for safe storage and technology for reusing the granules. However, these solutions are often not used. Granules should be disposed as hazardous waste. Hazardous waste operators charge high gate fees. Many clubs struggle to find inexpensive disposal solutions for used granulates. This increases the risk of improper storage and illegal dumping. Several instances of this have been documented.
Objective	The aim of this measure is to reduce the risk of losses by safe storage and reuse solutions.
Description	A storage for both new and used rubber granulate should be able to keep the material safely during both heavy rain, snow and flooding events. Fire is also a hazard. Machines for preparing the granulate for reuse should be available at a reasonable scale. Delivery of used granulate that cannot be reused should have to be in place in a region before a turf is allowed established.
Possible incentives	Better implementation and follow up of requirements from the Ministry of Culture. Including promotion and education on guidelines for best practice. Local regulations and inspections.
Reduction potential	Not assessed
Cost estimates	Moderate costs
Feasibility	Dumping of such material outside the waste system is illegal already. Storage solutions exists. There is an interest for voluntary commitment and/or a take back obligation.
Link to other measures	Measure 13.2 and 13.3. Generic measure 5.2 Voluntary commitment including a take back solution and 5.7 Flood preparedness.

14 Assessment of reduction potentials and measures for wastewater collection and treatment

14.1 Conclusions and summary

The measure considered is based on the conditions for the Norwegian system of wastewater collection and treatment. The conditions are somewhat different from other countries when it comes to treatment requirements and standards. These can entail differences in emissions requirements in permissions, number of plants without chemical and/or biological treatment, preparation for new requirements and treatment steps.

Possible reduction in discards of microplastic at sewage treatment plants is the most relevant measure investigated in this report, mainly concentrated on plants with chemical and/or biological treatment already in place, covering about 62 % of the population in Norway. Another approach would a be to change from mechanical treatment plants to chemical/biological treatment with following removal of microplastic, covering about 20 % of population.

The knowledge to make good calculation about possible effects and the total cost is limited. A very rough estimate indicates a possible reduction of 430 tons microplastic in effluent from sewage treatment plants (STPs) yearly, representing 0,1 kg/capita to a possible cost of 150 NOK/capita. This measure will also have positive effects on other pollutants from STPs and the cost could be divided among several sources.

There are available technologies, for example micro filtering, that can be used and optimized for removal of microplastic. This requires an add-on solution as a last polishing step. Introduction of microplastic removal needs a legal framework in order to define relevant requirements in plant permissions. To incorporate new requirements in future EU-directive for urban wastewater will probably be the best way to ensure the implementation in Norway.

Measures in the transport system to reduce leakages are considered to be a constant ongoing activity based on general pollution control incentives. Special measures to reduce the effect of direct urban run-off are challenging, and it is assumed to have small effect on total discards of microplastic, even with more flood control installations.

There is a growing concern about the content of microplastic in the sludge, but available documentation on effects are little. About 86% of this sludge is used as soil-conditioner and fertilizer in total with 63 % used in agriculture. Improved waste water treatment should also focus on the challenge to possibly separate microplastic in a way to reduce the amount in fertilizer.

Table 14-1 Evaluation scores for measures against microplastics in waste water streams

No	Evaluation of measures - microplastic pollution from: Proposed Measure	Emission reduction		Cost Effective	Feasibility		Total score
		Tonnes reduction	Score 1-3	Cost per tonne Score 1-3	Available Techniques Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
14.1	Improved waste water treatment at chemical and/or biological treatment plants	**430**	2	1	*1,0*	0,5	4,5
	Other measures not calculated						
TOTAL REDUCTION POTENTIAL		**430**	**Out of a total estimated Norwegian discharges at source of 8400 tonnes of microplastics (2014)**				

14.2 Gross reduction potentials

14.2.1 Summary of gross potentials from Mepex report 2014

In the Mepex report from 2014, table 8-2 gave a best guess on the probable share of generated microplastic from different sources that goes to the sea. In total the report estimated a possible level of generation on 8.400 tons/year, equivalent to about 1,65 kg per capita per year. The rough estimations said that about 50 % of this is expected to end up as emissions to the sea.

The report did not make an estimation on the amount sent to sewage treatment plants (STP) and the emission in effluent from the STP, nor the separate issue of urban run-off systems with direct emissions to the sea.

14.2.2 Adjustments and prognoses based on new knowledge

In this report, we go into a more detail about transportation and treatment based on Norwegian conditions in order to determine the total potential for emission reduction in wastewater systems.

Municipal transport systems

Microplastics can be transported in different sewer system and in separate storm water pipes. Storm water is normally going directly to local waterways untreated. It is not usual in Norway for retention basins to take the first flush.

The statistics for municipal sewer system, counted in length:

- Separate sewage system 29.000km
- Combined system for sewage and storm water 7.500 km
- Separate storm water system – 16.500 km

Combined systems are normally in city centre areas with a high degree of paved surface area and drainage to the sewer system. This also causes problems with overflows during strong rainfalls.

It is also important to take into account losses of water, including the pollutants in the water. The losses can be divided into:

- Leakage in pipes and gutters into the ground (combined systems)
- Leakage in pipes and gutters into a underlying storm water pipe (separate systems)
- Leakages in water overflow in combined systems (during rainfalls or technical problems)

A rough estimate is that about 15 % of the total water is lost during transportation, and about 5-10 % of this is directly transported to waterways from overflow points and leakages into storm water pipes underlying sewage pipes.

Waste Water Treatment and sludge

Waste water treatment methods in Norway are measured based on person equivalents[71]. Local treatment is normally covering 1-2 households and is small units in rural areas[66]. The figures 14-1 and 14-2 show the types of treatment in place up until 2013.

- 62 % to chemical and/or biological treatment
- 20 % mechanical treatment
- 18 % local treatment, septic, sand filters

[71] Kommunale avløp, Report 41/2014, Statistics Norway

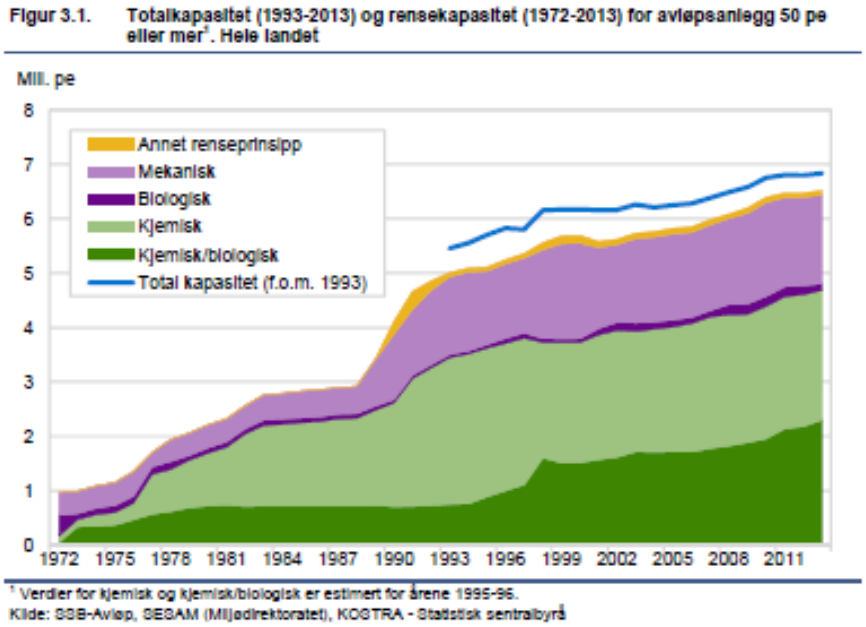

Figure 14- 1 Waste-water treatment methods in Norway

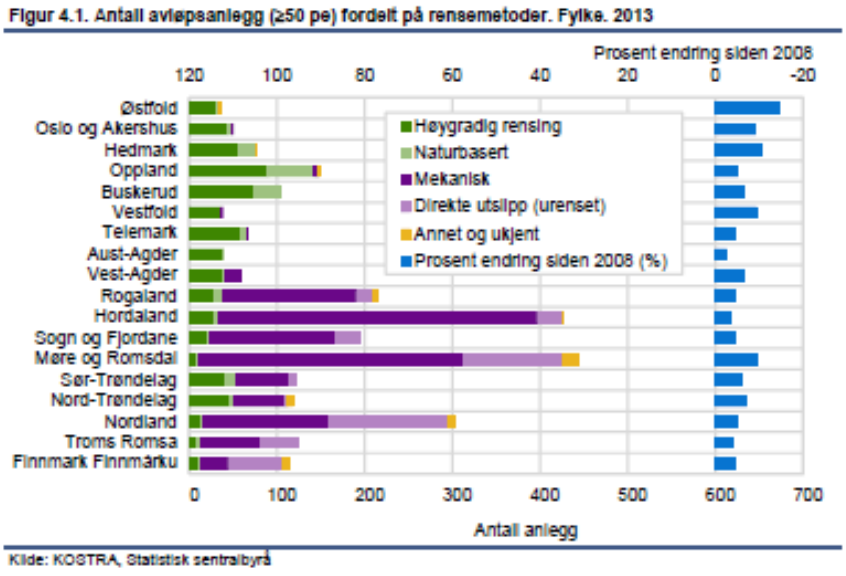

Figure 14-2 Number of treatment plants with different treatment methods

Disposal of products from sludge treatment in 2014 is divided in following markets :

- 86 % used as soil conditioner and fertilizer
- 13 % covering at landfills
- 1 % landfilled

Figure 14-3 show the development from 1994-2014 in tonnes.

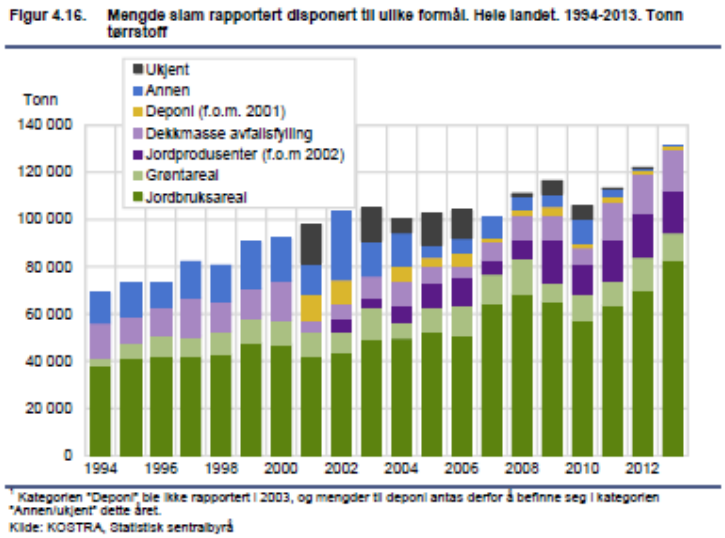

Figure 14- 3 Final disposal of sewage sludge in Norway

14.3 Description and selection of measures

Table 14-2 Possible measures (longlist) for waste water collection and treatment

No	Measure	Comment
14.1	Improved waste water treatment	Effective measure
14.2	Improved collection system	Ongoing activity
14.3	Reduction in overflows	Ongoing activity
14.4	Filter systems for small scale solutions Improved drain sand-traps	No references Unsure effect
14.5	Changes in sludge treatment	New ideas

Based on total assessment, this report focuses on improved waste water treatment at central treatment plants for more than 50 pe. This covers about 80% of the sewage production in Norway.

Special filter systems for small scale plants, typical for 1-2 households in Norway should also be considered in the future, but will represent other challenges in operation, maintenance and control. We can expect that all these small sources result in some effluents to small rivers and sweet water recipients.

In general there is a focus to reduce the leakage of waste water in the transport system into sewage treatment plants, but this work is long term and will last for a minimum of 100 years for renewal all pipes. Reduction of storm water overflows in combined transportation systems is also normally covered in existing plans, especially in areas with strict hygienic water standards.

The structure of the urban runoff systems and separate storm water systems can also be subject to measures in order to have better control of surface pollutants from urban areas sent directly to the nearest waterway. In some cases there may be solutions that consist of constructing basins for the first flush that can be lead into sewage system or to build capacity in sewage systems to receive more polluted storm water.

Improved drainage systems and retention basins for first flush can be possible measures, but difficult to build on large scales in cities and municipal centers. However, this measure may be considered more relevant for road authorities.

14.3.1 Measure 14.1 Implement improved waste water treatment technology

Criteria	Comments
Background	In Norway there are different requirements for waste water treatment plants depending on size and geographic location and recipient. Along the coast from Lindesnes to the Russian border there is the possibility to apply only primary treatment requirements and this has resulted in mostly mechanical treatment, except some areas, for example, Bergen. This is only for discharges to sea and not lakes/rivers. New filter technology for advanced cleaning effluent water for particles also demands total rebuilding of treatment plants in some instances. In the Skagerrak area from Swedish border to Lindesnes normal treatment is based on chemical treatment and chemical/biological treatment. Biological treatment will be included more and more in the future. The policy up till now in Norway has been to focus on source reduction of all harmful and hazardous content in waste water, that is not prepared for more advanced treatment plants. It is not the ideal situation if new requirements for microplastic removal call for new treatment steps.
Objective	The objective for this measure is to implement better waste water treatment technology to remove microplastic in STPs in an efficient way. If possible this should not give extra content of microplastic in sludge used as a fertilizer.
Description	Experience regarding sewage treatment to capture microplastic is limited. There are several international reports, but the value of

	them is limited, both because they are based on few samples and not necessary representative of Norwegian conditions. It's hard to build clear conclusions based on these and there are still many uncertainties. The effect of retention is dependent on particle size and normal ranges from the literature are:[72] • 300 µm - 94-97% • 20-300 µm – 70-90 % • < 20 µm – no data available This study has chosen to use the experience with removal of suspended substances (SS) and made an assumption that there is a connection between technologies for particle removal in general and removal of microplastic particles. A surrogate parameter like total suspended substances (SS) should be investigated. Here there is an accepted analysis method and both 0,45 and 1,2 µm glass fibre filters are possible. It is also noteworthy that different available technologies are described and evaluated based on Norwegian conditions. The following technologies are considered as separate cleaning/polishing and treatment steps that can be added after conventional biological/chemical steps. - Different kind of sand filters (discontinuous or continuous) - Sand filter with regenerated hydrous ferric oxide chemicals - Drumfilters with micro filter disks (from 10 µm) The membrane bioreactor (MBR) is more suitable for new treatment plants or existing plants with only mechanical treatment. Pore size in the filters is normally lower than 0,5 µm. Normal reported concentration of SS in effluent water are: - 1-5 mg/l Sand filters (discontinues or continues) - 0,6-1,8 mg/l Sand filter with hydrous ferric oxide - 2,3-3,1 mg/l Drum filters with micro filter disks

[72] Microplastics, occurrence, effects and sources of releases to the environment in Denmark. Cowi for Danish Ministry of Environment, Aug. 2015

	- < 1 mg/l Membrane bioreactor Normal concentration for STP with biological/chemical treatment can be 10-20 mg/litres. The last step with an effective filtering system can give an additional retention of 90% for particles in general and we assume just as effective for microplastic.
Possible incentives	The incentives towards this measure have to be based on new strict regulations from authorities for microplastic discharge. New EU-regulation including microplastics could be the most effective way to implement this measure in Norway. It's likely to assume that a specific national regulation for Norway in this area is not very realistic based on STP structure and policy.
Reduction potential	It's too early to make good calculation about possible effects. If we assume that 5000 tons is the amount going into a sewer system with treatment, we calculated that about 1400 tons is effluent from sewage treatment plants currently. This is based on average retention effect on 85% for plants with chemical/ biological treatment and zero for mechanical treatment. If all plants with existing chemical and/or biological treatment add a filter system that can give 99% of retention effect on microplastic in effluent water, we can obtain a total reduction of 430 tons/year.
Cost estimates	This measure requires large investment and including operation, energy and maintenance costs. There is no good platform to give a cost calculation. Based on rough estimates the total cost can be 4000 mill NOK in investments and yearly operation cost from 100-300 mill NOK. This is based on sand filters, but we expect drum filters to have some lower costs. Yearly costs could be about 700-800 mill NOK, representing about 1,7 mill NOK/tons.
Feasibility	The different technologies are available and can be developed more in order to optimize microplastic removal. There is need for more practical experience to find out the best choice of technology under different conditions. The legal framework to define new criteria's in plant permission about microplastic should be developed. We can except that plant owners will take legal steps in order to clarify if such requirements can be stated, based on the existing Pollution Act. An revision of EU regulation on waste water treatment with defined requirements for either retention degrees or effluent

	concentration for microplastic may be most effective.
Link to other measures	Almost all sources of microplastic will partly end up in the sewer systems and transported to Sewage treatment plants. It will therefore be necessary to develop a national strategy where measures to reduce the emission at source has to be seen in connection with possible end of pipe solutions at STP.

14.4 Generic measures

In general the main target group for measures under this chapter is the municipals and authorities, but also scientific researchers and NGOs.

There is certainly a need for more Research and Development activity within the area of transport of microplastics in waste water systems and effluent from treatment plants. This may cover:

- Improving test methods for surveys to document microplastics flows in waste water and search for relevant surrogate parameters (SS)
- Programs to analyse different plants to have more specific knowledge about this problem
- Testing different treatment methods
- More knowledge about sludge treatment and effects in agriculture

There is also a need for making a network for further activities and facilitating a climate for good cooperation with the waste-water sector.

In terms of legal instruments, there could be some requirements for microplastic emission measurement relevant to start-up of new facilities.

15 References and acronyms

15.1 Literature

Literature we have listed as footnotes in the text of this report.

15.2 Photos

All pictures belong to the authors except on the frontpage.

15.3 List of personal communications

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15.4 Abbreviations and acronyms

ASTM	American Society for Testing Materials (an international standards organization)
ELV	End of Life Vehicles
EPDM	Ethylene Propylene Diene Monomer (used at football pitches)
EPR	Extended Producer Responsibility
FFI	Fauna and Flora International
HELCOM	The Helsinki Commission
NGO	Non-Governmental Organisation
NOK	Norwegian Kroner
OSPAR	Oslo and Paris Conventions for protecting the marine environment
PE	Polyethylene
PP	Polypropylene
R&D	Research and development
SBR	Styrene-Butadien Rubber- a synthetic rubber from tyres
TPE	Thermoplastic elastomer, rubber
WEEE	Waste from Electric and Electronic Equipment

16 Appendix 1- Scoring overview all measures

The multi- criteria evaluations summarized below are just the first step to developing and evaluating a package of measures. We need, for several reasons further discussions on the composition of specific vs generic measures as basis for a good strategy:

- Some measures can be easily implemented while others have a longer perspective.
- Some measures prevent emissions, while others remove emissions during, or at the end of particular processes.
- Lastly, although our level of knowledge is improving day by day with new studies and data sources becoming available –there are still huge knowledge gaps.
- A strategy has to be flexible and open for new actions, international cooperation and decisions.

In the tables below, we have summarized all the generic measures and then the specific measures described in this report and assigned them scores for costs, efficiency and expected feasibility (equally weighted); 3 being the best score for each criteria.

In general, measures with total score 6 are recommended. However, other measures should be considered too, as part of a package of several measures.

In the first table below, we summarize the evaluation of different generic measures, described further in chapter 5. Generic measures considered as basic investments for other measures, for example competence, we give a high score. In further discussions and evaluations on measures, authorities should also take a good mix of measures (*i.e.* 'reward and penalty', 'direct and indirect'') into consideration.

However, the evaluation is rough, based on our own judgements/ and our interpretation of the best knowledge available. Some other measures obtain nearly identical scores. We give the lowest score (possible) to a promotion of biodegradable alternatives because we believe there is simply not enough known about biodegradation of "biodegradable plastics" in the ocean. Instead, more R&D is needed, inclusive of R&D on substitution alternatives and their impacts. The low score of clean-ups is based solely on the fact that clean-ups of microplastics, on any more than a very small scale, is just too costly.

In society in general, we are preparing for flooding and climate change. The high score of measure 5.8 indicate that these preparations should include the issue of microplastics (as well as marine litter in general).

Table 16-1 Evaluation of proposed generic measures

No	Proposed Measure	Emission reduction	Cost Effective	Feasibility		Total score
		Score 1-3	Cost per tonne Score 1-3	Available Techniques Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
5.1	Competence, knowledge and best practice	3	3	1	1	8
5.2	Voluntary commitments	2	3	1	1	7
5.3	Legislative clarifications	3	3	1.5	1	8.5
5.4	Restrict use of microplastics	1	2	1	1	5
5.5	Monitoring rivers and coast	2	2	1	1	6
5.6	Clean ups	1	1	1.5	1	4.5
5.7	Flood preparedness	2	2	1	1.5	6.5
5.8	Ecolabel and Public procurement	1	2	*1*	1	5
5.9	Biodegradable substitutions and standards	1	1	1	1	4
5.10	R&D on microplastics	3	2	1	1	7
5.11	National action plan	3	3	1.5	1.5	9
5.12	Develop further knowledge on pollution sources	3	2	1	1.5	7.5

In the table below, we summarize the evaluation of different specific measures.

Table 16-2 Overview table, evaluation of all specific measures proposed

Evaluation of measures - microplastic pollution	Emission reduction		Cost Effective	Feasibility		Total score
			Cost per tonne	Available Technique	Existing initiatives	Sum
Source Group/Sub group/Measure	Tons	Score 1-3	Score 1-3	Score 0,5-1,5	Score 0,5-1,5	Score 3-9
6. Road traffic						

Evaluation of measures - microplastic pollution		Emission reduction		Cost Effective	Feasibility		Total score
				Cost per tonne	Available Technique	Existing initiatives	Sum
Source Group/Sub group/Measure		Tons	Score 1-3	Score 1-3	Score 0,5-1,5	Score 0,5-1,5	Score 3-9
Tyres & Road paint	6.1 Reduce road traffic (ref 2016)	750	2	2	1.5	1	6.5
	6.2 Low emission tyres		1	2	0.5	0.5	4
	6.3 Eco driving	500	2	3	*1.5*	1	7,5
	6.4 Improve roads		1	1	1	0.5	3.5
	6.5 Road cleaning	750	3	2	1.5	1.5	8
7. Paint							
Marine & Buildings	7.1 Alternative paint formulas	500	3	2	1	0.5	6.5
	7.2 Dust and spill control	450	2	3	1.5	1	7.5
	7.3 Paint leftovers delivered	100	2	3	1.5	1	7.5
	7.4 Water treatment	450	2	1	1	1	5
8. Textile fibres							
	8.1 Reduction in use of synthetic textiles						
	8.2 New test method	-	1	3	1,5	1,5	7
	8.3 Improved design/production	280	2	3	1,5	1,0	7,5
	8.4 Filters on washing machines	350	2	2	*1,0*	1,0	6
9. Cosmetics							
	9.1 Follow up on industry commitment in Norway		2	2	1,5	1,5	7
	9.2 Follow up on European and US development		2	1	0,5	1	4,5
	9.3 Ban the use of microbeads		2	1	0.5	0.5	4
	9.4 Research on alternatives		2	1	0.5	1	4.5
	9.5 Eco label and Public procurement		1	2	1	1	5
	9.6 Stimulate positive guidelines		2	3	*1*	1	6
10. Pellet Loss							
Plants & Transport	10.1 Voluntary commitment		2	3	1.5	1.5	8
	10.2 Included in plant permit & reporting		2	3	1.5	1.5	8
	10.3 Increased monitoring		2	2	1	1	6
	10.4 R&D, best practice on		2	1	1	1	5

Evaluation of measures - microplastic pollution Source Group/Sub group/Measure		Emission reduction		Cost Effective	Feasibility		Total score
		Tons	Score 1-3	Cost per tonne Score 1-3	Available Technique Score 0,5-1,5	Existing initiatives Score 0,5-1,5	Sum Score 3-9
	logistics						
11. Waste and recycling							
Paper, Plastics, Organics	11.1 Monitoring emissions	**0**	1	1	1.5	0.5	4
	11.2 Investigation and risk assessment	**0**	1	1	1.5	0.5	4
	11.3 Develop technology	**0**	1	1	1.5	0.5	4
12. Offshore and other industrial sources							
Offshore Industry	12.1 Further investigation	0	1	1	1.5	1	4.5
	12.2 Environment classification	0	1	1	1.5	1	4.5
	12.3 Reporting obligation	0	1	1	1.5	1	4.5
	12.4 Regulatory binding definitions of microplastic	0	1	1	1.5	1.5	5
13. Other sources							
Football pitches	13.1 Promote Natural pitches	n.a	1	2	1.5	0.5	5
	13.2 Better construction	n.a	2	2	1.5	1.5	7
	13.3 Safe sweeping and snow removal	n.a	2	2	1.5	1.0	6.5
	13.4 Safe storage for reuse and take back	n.a	2	2	1.5	1.0	6.5
14. Sewage and stormwater treatment							
Waste water	14.1 Improved waste water treatment at chemical and/or biological treatment plants	**430**	2	1	*1,0*	0,5	4,5
TOTAL REDUCTION POTENTIAL			**Out of a total estimated Norwegian discharges at source of 8.400 tonnes of microplastics (2014)**				

17 Appendix 2- Details on the discussion about the definitions of microplastics

In order to obtain a better understanding of the issue of microplastics and develop better estimates on the different sources, we proposed the following in the previous Mepex report:

- As a first priority, more elaboration on the definitions of microplastics and criteria for what is microplastics, including a definition of "solid particles".
- In addition, we need a better overview of all kinds of particle sizes, even Nano particles and particles larger than 5mm. Such an overview can also serve as basis for a better understanding of degradation processes.

In addition, a better understanding of all particles and dust in the environment seems to be relevant for a holistic approach and understanding. All kinds of particles, including larger plastic particles (larger than 5mm) and other organic particles should be analyzed further.

We will also propose a discussion on the definition of when a microplastic is no longer a microplastic – i.e. at what size/chemical process can the plastic be considered 'broken down' and benign environmentally, if at all.

OSPAR published a background document of microplastics on 30 September 2015. This document defines and discusses further the issues of "solid" particles and "soluble" particles.

Eunomia, in their draft report of 2015, also discuss different definitions used in literature and in legislation.[73] The report also describes the grey zones between solid particles and different kinds of waxes. The grey zones are crucial for understanding microplastics used in cosmetics as different stakeholders so far define microplastics differently.

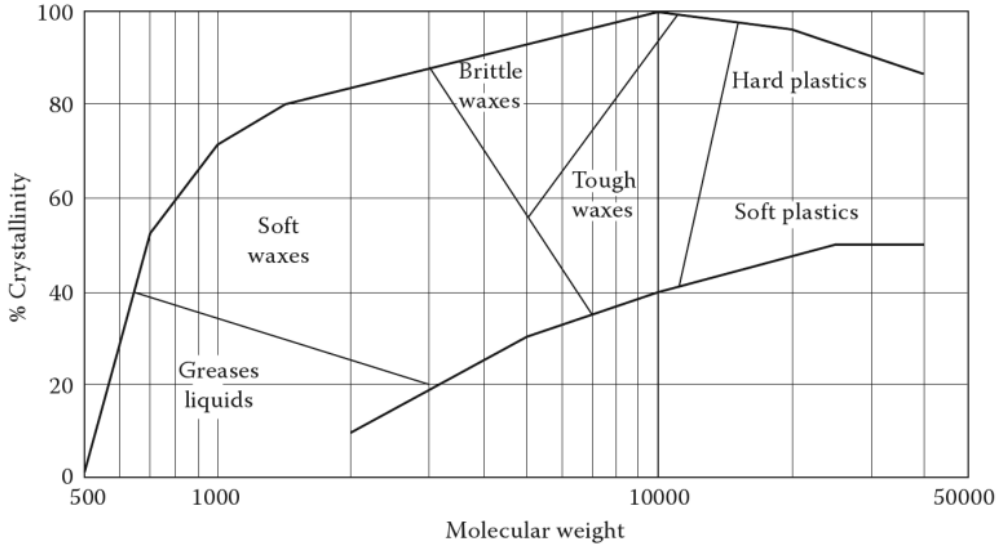
Deciding whether a polymer particle should be classified as micro plastics largely comes down to whether it can be classified as a liquid or a solid.[74]

Figure 4-1 below, from the draft Eunomia report, shows how the physical properties of polyethylene change based on its crystallinity and molecular weight. Highly crystalline polymers with a high molecular weight are hard, however there is a significant 'grey area'

[73] Hann, Simon, Eunomia. 5 September 2015, Study to support the development of measures to combat a range of marine litter sources. WP 2: Preliminary scoping exercise of options to achieve a phase-out or ban of microplastics in cosmetic products. Report for DG Environment, European Commission.

[74] Leslie, H., and et al. (2014) Review of Microplastics in Cosmetics, Report for Dutch Ministry of Infrastructure and the Environment, July 2014

during the transition from hard plastic to soft wax—with a molecular weight of over 7,000—where it is possible that these other forms of polymers could be considered marine litter.



Source: Engineering Design with Polymers and Composites[75]

Figure A2-1 Plastic can come with many physical properties. Example: Polyethylene

As part of the discussion on the definition of microplastics, it is also important to land a common international understanding about if just the polymer part of the product or the whole solid content (including other fillers and materials) should be included in the volume estimates. In our 2014 report estimating sources in Norway, we chose to count only the polymer part of paints and tyres. We stay with this method in this report, but point out that when discussing measures, most often the whole particle of for example, paints and tyres, has to be handled properly. In some contexts it therefore seems meaningful to include the whole substance-matrix of the particles in discussion of weight measures. This also includes artificial football pitches.

One more question for the definition of microplastics is if there should be a lower cut-off, e.g. 10% or similar, for polymer content in particles that are called microplastics. One example could be concrete with a polymer additive. For all practical purposes, the sources and volumes mentioned in this report that are plastics, are based on products and particles with a high polymer content, from around 50% and above.

Based on our experience from two Mepex reports, we believe the word “microplastic” and the definition hereof make communication and understanding difficult.

[75] James C. Gerdeen(2005) Engineering Design with Polymers and Composites, CRC Press