Environmental Impacts from Road Markings in Germany

Introduction

The European Union (EU) has dedicated itself to sustainable development and has set a very ambitious target of making Europe the first climate-neutral continent by 2050. To achieve this ambition, the EU introduced the European Green Deal in 2019, which consists of dedicated regulations, strategies and funding mechanisms that address eight major policy areas European Green Deal - KPMG Global. The European Green Deal (COM(2019)640 final) sets out four interlinked policy goals for the transition to a sustainable economy and society: climate neutrality, biodiversity protection, circular economy and a zero pollution ambition for a toxic-free environment. On the climate area all 27 EU Member States pledged to reduce emissions by at least 55% by 2030 compared to 1990 level Delivering the European Green Deal (europa.eu).
Environmental impacts of products and services from a life cycle perspective (Life Cycle Assessment – LCA) need to be considered when taking decisions about alternatives. ISO 14040/44 provides the guidelines for evaluation of environmental impacts of products, including Global Warming Potential (so-called CO2 emissions), considering all material and energy input along the whole life-cycle. ISO 14025 sets the framework for 3rd party verified environmental claims (type III environmental labels). Environmental Product Declarations (EPDs) are such voluntary labels based on ISO 14025 that communicates quantitative information on environmental impacts of products based on a underlaying LCA in a standardized manner. According to ISO 14025, a Product Category Rule (PCR) is the compilation of specific rules, requirements, and guidelines for creating EPDs in one or more product categories. EN 15804 specifies the basic rules for EPDs in the category of building products. These fundamental product category rules ensure that all EPDs for construction products, building activities, and construction processes are derived, depicted, and verified in a uniform manner For instance, EN 15804 stipulates the conditions for EPDs that are valid Europe-wide EPD Programme at IBU | Institut Bauen und Umwelt e.V. (ibu-epd.com).
Road markings are subject to constant wear by traffic and other impacts such as snow plowing during winter maintenance, for instance. A variety of road marking systems are available to cope with different climatic conditions during installation and different wear conditions on the road, and most important, to provide different safety features that provide road safety at all conditions. Tin layer paint-type systems provide good enough durability on roads with low traffic wear, but they abrade quite fast at high traffic wear and require frequent renewal to maintain the markings visible at night. For high traffic wear various durable road marking systems are available, that can be textured to provide additional safety functionalities that thin flat systems cannot deliver. No specific PCR for road markings is available to provide a basis for a meaningful assessment of environmental impacts of road marking systems considering the conditions and performance in the use.

Background

EU JRC has reviewed road marking technologies in the following manner Technical Report for Paints Varnishes and Road Markings (FINAL).pdf
In accordance with EN 1436 road markings form a part of the means for horizontal signalization. They include longitudinal markings, arrows, transverse markings, text and symbols on the surface of the road and can be 'provided by the application of paint, thermoplastic materials or cold hardening materials, preformed lines and symbols or by other means'. Road markings can be applied with or without the addition of glass beads. Majority of road markings are white or yellow. Glass beads are tiny spherical glass balls used to achieve the retroreflection of the marking when the road marking is illuminated by vehicle headlamps. This retroreflection can also be improved, particularly for wet or rainy conditions, by special properties produced e.g. by the texture of the surface (in structured markings) or addition of large glass beads. Application of surface texture causes additionally that wheels of the passing vehicle

can produce acoustic or vibration effects. Glass beads are dropped on top of freshly applied road marking and/or can be mixed in with marking before it is applied. Glass beads can be treated to promote the good and correct embedment into the road marking product, with adhesion and flotation coating, or the combination of the two, to endow the road marking of retro reflection properties during lifetime.

Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

Additionally the glass beads can be mixed with anti-skid aggregates to ensure the grip on the marking. There are various material technologies with different solidification methods used in road marking systems:

– Water-borne paints – sprayed on the road surface, dry by coalescence and water evaporation, form a thin layer;

– Solvent-borne paints – sprayed on the road surface, dry physically by evaporation of solvent, form a thin layer;

– Thermoplastics – applied in the molten state at about 200°C, either sprayed on (thin layer) or casted on as a melt (thick layer), solidifying by cooling;

– Reactive road marking systems (the so-called 2-component cold plastics) – mixed with a second hardener component. They are applied at ambient temperatures (are sprayed on (thin layer) or casted on (thick layer)) and solidify by chemical curing into an inert duroplastic polymer.

These major road marking systems that are being formed on road site by applying a liquid road marking material and broadcasting glass beads on the material before solidification. Road marking materials are formulations of a binder resin, pigment (typically titanium dioxide), fine and optional coarse fillers (including fine premix glass beads) as well as additives, in general.

Besides these liquid applied road marking systems other technologies manufactured off-site such as preformed tapes, for instance are occasionally used. Tapes for permanent road markings are typically composed of a self-adhesive layer an elastic rubber layer with hard polyurethan topcoat and embedded ceramic beads and ceramic anti-skid aggregates.

The importance of glass beads for the functionality of road markings as far as night-time visibility (retro-reflectivity) is concerned as well as the importance of in-use durability of road marking systems for environmental impacts of road marking was highlighted by the JRC background report.

Cradle-to-grave LCA study for four types of road marking systems

A comparative, cradle-to-grave LCA study of the four major binder-based material technologies in the context of German road marking practice that was reviewed and certified by an independent expert panel according to ISO 14040 and ISO 14044 [Evonik Industries AG, Life Cycle Assessment of Road Marking Substances and Systems, 2011], [Intertraffic World, 'Life cycle under the lens', Annual Showcase, 2012] [Evonik, Vergleichende Ökobilanz-Studie für Straßenmarkierungssysteme“ Lacktagung, Bremerhaven, 2012] analyzed the following environmental impact categories:

- Global warming potential (GWP100) [kg CO2-equiv.];
- Acidification potential (AP) [kg SO2-equiv.];
- Eutrophication potential (EP) [kg phosphate-equiv.];
- Photochemical ozone creation potential (POCP) [kg ethene-equiv.]; - Human toxicity potential (HTP) [kg DCB-equiv.];
- Terrestric ecotoxicity potential (TETP) [kg DCB-equiv.];
- Freshwater aquatic ecotoxicity potential (FAETP) [kg DCB-equiv.];
- Primary energy demand as an additional criterion.

The analysis was conducted on a marked one-kilometer road section equipped with a middle stripe and two edge lines with 280 m2 marked area in total for an evaluation period of 10 years.

Typical material formulations in characteristic application scenarios have been modelled using the data of corresponding official approval test certificates held by a major local manufacturer of all evaluated technologies. These certificates issued by the German Bundesanstalt für Straßenwesen (BASt – Federal Highway Research Institute) define, for instance, both the marking material and the broadcasted glass bead aggregate mixture along with the proper specific consumption per square meter that must be applied in practice on the road to comply with German performance standards in place at the time

(2011). These standards – DIN EN 1436 and ZTV M 02 – specified minimum thickness and performance figures, such as coefficient of retro-reflected luminance (RL) of the road marking, for example. Safety markings with high wet night-time visibility – so-called Type II markings – are characterized by a coefficient RL measured at a wet condition of at least 35mcd/m2 lx, for instance. The service life of such road markings is given by the time during which retroreflection remains above this threshold under traffic load. In use-service life (lifetime) of the various systems on a typical German federal road bearing an average traffic of about 10000 to 15000 vehicles per day has been taken from empirical observations. These empirical figures are well in line with independent publications on relative lifetime of road marking systems Ökopol und IER Universität Stuttgart “European directive limiting the VOC content in certain

Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

products [Report on potential extensions of the directive covering road markings – Review of Directive 2004/42/EC, published 2011 and references therein].

For all the systems, the environmental impact of the production, including the contributions of raw materials and energies up to the formulator's factory gate ("cradle to gate"), was first analysed per kilogram of produced road marking material. The analysis was then extended to the entire life cycle, through application and repainting, all the way to disposal ("cradle to grave") with impacts calculated per kilometer and per 10 years.

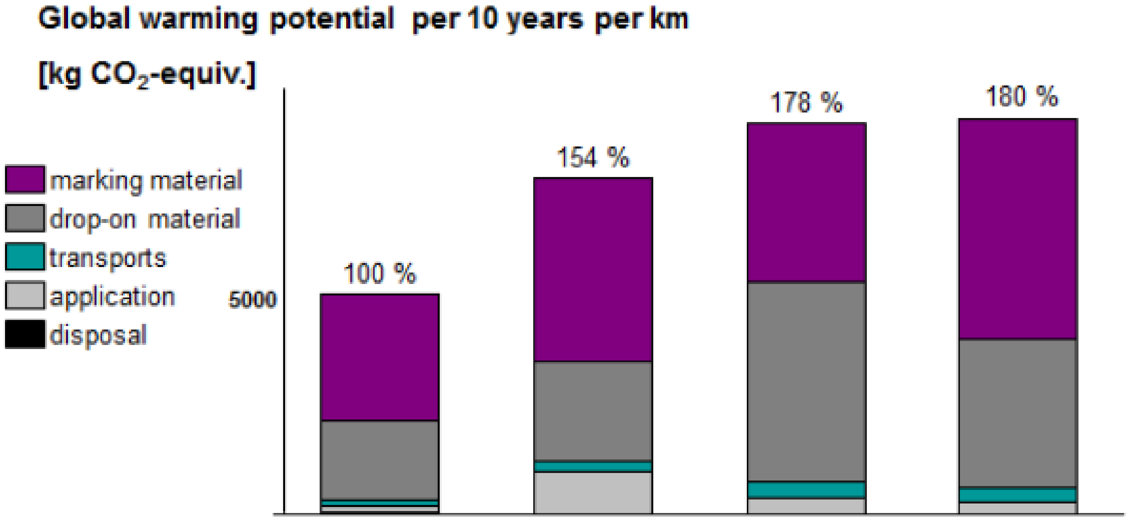
"Cradle to gate" examination: The environmental impact up to the factory gate is determined by the contributions of the formulation raw materials, while the formulation process as such and transportation, packaging, and wastes play a subordinate role. Among the formulation raw materials, energy-intensively produced substances such as the titanium dioxide pigment, glass beads in the case of CP and TP, solvents in the case of solvent-based paints, and the binder itself contribute the most to the ecological impact. The analysis shows that toxicological environmental impacts cannot be deduced exclusively from the statutory hazardous-substance classification of the formulation components. For example, the main contribution to the human toxicity potential per kilogram of cold plastic formulation arises not from the reactive resin binder, but from the titanium dioxide pigment in the formulation. The human toxicity potential per kilogram of water-based paint is not considerably lower since it contains similar amount of titanium dioxide.

"Cradle to grave" examination: The question of the environmental impacts arising per kilometer of marked road over an observation period of 10 years for the choice of a particular product alternative investigated safety markings with enhanced wet night-time visibility (type **II**), for instance. The study considered the following marking scenarios, which correspond in practice to the major applications: Thin layer (CSP, TSP, SB, WB), thick layer flat line (CP, TP) and thick layer agglomerates (CP, TP).

Thin layer: All the four road marking systems respectively binder technologies can be considered for laying of thin-layer road markings. Transports, application and disposal do not contribute significantly, except for thermoplastic application where the material needs to be heated up to about 200°C to melt process it. However, Solvent-based or water-based systems have proven in practice to be much less durable than cold-spray plastics, so that significantly more material is consumed for the maintenance of a marking over a 10-year period. Spray applied thermoplastics are also durable, but in this case a long lifetime is achieved at the cost of high material consumption per application. It is evident from Figure 1 that for all systems the consumption of marking material and drop-on material dominates the life cycle assessment, while transport and application contribute much less to the global warming potential. This applies even to thermo spray plastic, which is processed at temperatures that may exceed 200°C. Similar trends have been found for Type **I** and Type **II** spray systems.

Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de



	CSP	TSP	Water	Solvent
Thickness / mm	0.6	1.2	0.6	0.6
Lifetime / a	2.5	2.0	1.0	1.0

Figure 1: Global warming potential of various spray applied road markings per 10 years and road kilometer Source: Evonik, 2011 (Type II markings)

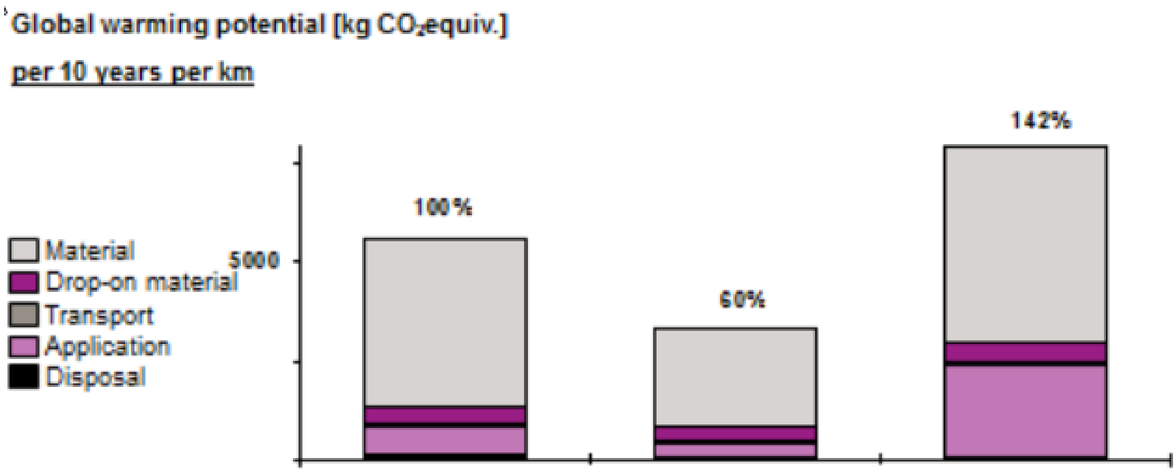
Structured road markings: The study of a thick-layer agglomerate road marking shows how strongly the life cycle assessment of marking systems is determined by the application conditions and usage or wear characteristics. Figure 2 shows a comparison of the impacts on the global warming potential for the following cases:

a) Cold plastic (CP) agglomerates are applied and after the end of their useful life are removed and then renewed in the same way as thick layers.

b) Cold plastic (CP) agglomerate is refreshed several times after the end of its useful life with thin-layer cold-spray plastic (CSP), with a lifetime that is then shorter.

c) Thermoplastic (TP) agglomerates are applied, and after the end of their lifetime are removed and then renewed in the same way as thick layers.

Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa
Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de



	Cold plastic	Cold plastic + 3 x cold spray (0,3 mm)	Thermo plastic
Relative Lifetime	4	4 (2)	3
No. of applications	3	1 + 3	4

Figure 2: Environmental impacts for structured road markings with cold plastic (CP) or initial application of cold plastic refreshed three times with 0.3 mm cold-spray plastic (CP+ 3 x CSP), or thermoplastic (TP) Source: Evonik, 2011

Remarks on the comparative LCA study

- Preformed road marking tapes have not been included.
- Environmental impacts shall be evaluated per square meter of marked area rather than per kilometer. This functional unit (square meter of marked area) is more common and handier for comparison.
- Evaluation period shall be 15 years rather than 10 years. Typical pavement life before renewal is required is 15 years for primary roads, respectively 25 years for secondary roads [„Chancen und Risiken der Lebenszyklusbewertung in Straßenbau und -erhaltung“ K. Mollenhauer, 19. Januar 2022 Asphaltstraßentag VSVI Hessen].
- Latest revision of German guideline ZTV-M13 has introduced lower limits for retro-reflectivity in the use phase. Minimum value for retro-reflectivity in wet condition for Type II markings is now 25 mcd/m2/lx, while the minimum initial value remains at 35 mcd/m2/lx. This results in somewhat longer functional life of the markings in general.
- According to ZTV-M13 renewal of road markings is recommended when nighttime visibility falls below 80% of the minimum value of performance classes R2 for type I markings, respectively RW1 for type II markings, whereas the authors of the Evonik study assumed end of life, respectively renewal at exactly the minimum values.

However, the systems and application scenarios evaluated in this study are in accordance with current road marking practice in Germany and the latest revision of guidelines for road markings in Germany ZTV-M13. The qualitative findings of the study remain valid.

Deutsche Studiengesellschaft für
Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

Assessment of environmental impacts of road makings based on state-of-the art German road marking practice

For the analysis of microplastic emissions from road markings in Germany DSGS has gathered the following information on relevant systems and scenarios Microplastic Emmission from Road Markings in Germany and Austria (dsgs.de):

Application of road marking systems in Germany is currently done according to the guidelines of ZTV-M13. Hence only certified materials are applied with a dosage per sqm as specified by the corresponding approval test certificate. ZTV-M13 provides criteria for selection of road markings systems depending on traffic volume and specifies minimum requirements on performance of road markings with enhanced nighttime visibility in wet condition (Type II markings) or with standard nighttime visibility (Type I markings). Renewal of road markings is recommended when nighttime visibility of a marking in use falls below 80% of the minimum value of performance classes R2, respectively RW1.

Given this regulatory background and German road marking practice typical application scenarios for the various road marking material technologies in representative system composition are compiled in table 1. For instance, road marking paint systems are typically applied as Type I systems only on secondary roads with rather low traffic volume of less than 5000 vehicles per day, while thermoplastic or cold plastic is applied as Type II markings on highly trafficked roads with more than 10.000 vehicles per day on average.

Environmental impacts considering the use phase can be assessed individually for each system depending on the functional durability@80% of each system type when retro-reflectivity falls below 80% of the minimum requirement as well as on the functional durability, namely the time the system is used until visibility falls below 100% threshold value. Assessment of both functionality@ 80% and functional durability for the individual systems at the corresponding traffic load are based on practical experience at test field B4 (see Appendix A1 for agglomerated thermoplastics and cold plastics and profiled tapes) with rather demanding abrasion conditions as well as on empirical observations on other roads in Germany and data from road trial in Croatia [see Appendix A2].

Life cycle inventory of the Evonik LCA study from 2011 was used to recalculate cradle-to-gate environmental impacts of the various road marking materials and broadcast glass bead mixtures using the latest version of the LCA software from Sphera LCA for Experts (formerly known as GABI) Database used was Sphera CUP2023.1 and Ecoinvent 3.8 [RÖHM 2024].

Environmental impact categories were analyzed using the CML method [CML 2001] of the Institute of Environmental Sciences (CML) of Leiden University with the updated characterization factors of August 2016.

CO2 emissions of various road marking systems per 15 years per square meter of road marking applied in typical application scenarios as recommended by German guidelines ZTV M 13 have been calculated from the cradle-to-gate emissions of road marking materials and drop-on beads required to maintain the road markings at the given scenario and the respective functional durability at 80% of minimum retro-reflectivity in use phase of the particular system according to DSGS Microplastic Emmission from Road Markings in Germany and Austria (dsgs.de). Emissions from transport and disposal have been neglected for all systems, since these contributions are insignificant compared to the contributions of road markingmaterials and broadcast materials and application.. Functional durability and abrasion of permanent road marking tape systems have been assessed based on road practice (see appendix A1 and A1 and Average-wear-of-different-road-marking-systems-2022-10-17.pdf (dsgs.de)). CO2 emission was taken from Environmental Product Declaration for 3M™ Stamark™ High Performance Tape Series 380ESD IMP White Data (environdec.com)

The results for the typical application scenario are compiled in table 1.

Table 1: Global warming potential / CO2 emissions of various road marking systems per 15 years per square meter of road marking applied in typical application scenarios as recommended by German guidelines ZTV M 13

Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

Products	Range of application depending on averange daily traffic volume (vehicles per day)	Density	Solid content (%)	Dosage (g/m²)	% Premix beads	Erosion Factor according to practical experience on roads in Germany	Functionnal Durability at 80% of minimum retro-reflectivity in use phase required by ZTV-M13 Section 4.13 (Years)	Annual material loss (w/o premix) (g/m²)	CO2 Emission System (Material +broadcast material+application) (kg CO2e / m²)	Total material loss in 15 years (w/o premix) (g/m²)	CO2 Emission per m² system per 15 years (kg CO2e / m²)
Thermoplastic Flat Typ II	>10000	2	100	6000	30	0,5	8	263	12,32	3938	24,6
Cold Plastic Flat Type II	>10000	1,93	99	5790	25	0,15	8	81	10,60	1209	21,2
Thermoplastic Agglo Typ II	>10000	2,1	100	3700	30	0,7	8	227	6,82	3399	13,6
Cold Plastic Agglo Type II	>10000	1,93	99	2800	25	0,25	9	58	5,46	866	10,9
TP Spray Type II	>10000	1,92	100	2300	20	0,7	5	258	4,71	3864	14,1
SB Type I	< 5000	1,57	75	630	0	0,5	4	59	1,43	886	5,7
WB Type I	< 5000	1,6	75	640	0	0,5	4	60	1,23	900	4,9
CSP Type II	5000 - 15000	1,58	98	950	0	0,25	5	47	3,26	698	9,8
CSP Type I	5000 - 15000	1,58	98	640	0	0,25	5	31	1,76	470	5,3
Tape Type II profiled	>10000		100	2980	10	0,25	10	67	22,74	1006	45,5

Figure 3 displays the CO2 emissions for initial installation of the respective system split into contributions from road marking material, drop-on material and application. Biggest contribution is originating from the road marking material in general. Broadcast or drop-on materials mainly consisting of glass beads are the second largest contributor in case of paint and cold spray plastic systems, while machine fuel, cleaning agents etc. provide the smallest contribution. In case of hot applied thermoplastic systems application step is the second biggest source of CO2 emissions.

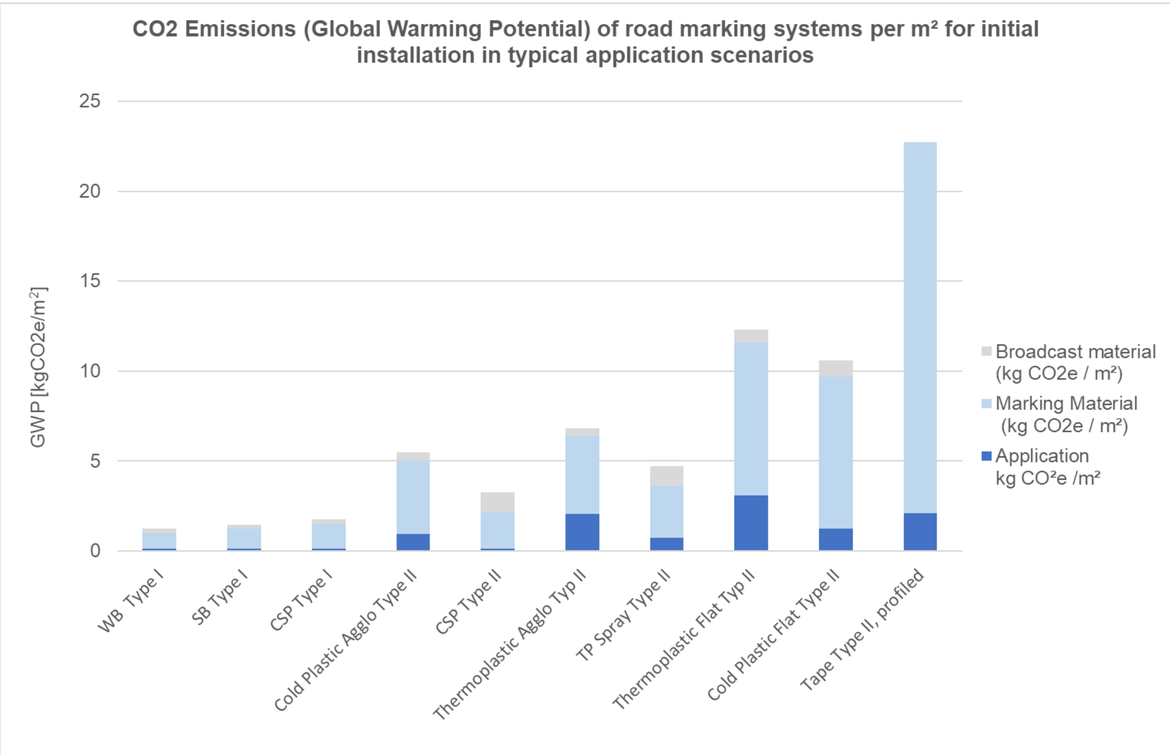


Figure 3: CO2 emissions for initial installation of different road marking systems in typical application scenarios broken down into contributions from road marking material, broadcast material and application.

Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

Figure 4 shows the total CO2 emissions over 15 years considering all renewals required to maintain the markings with the respective system in its typical application scenario.

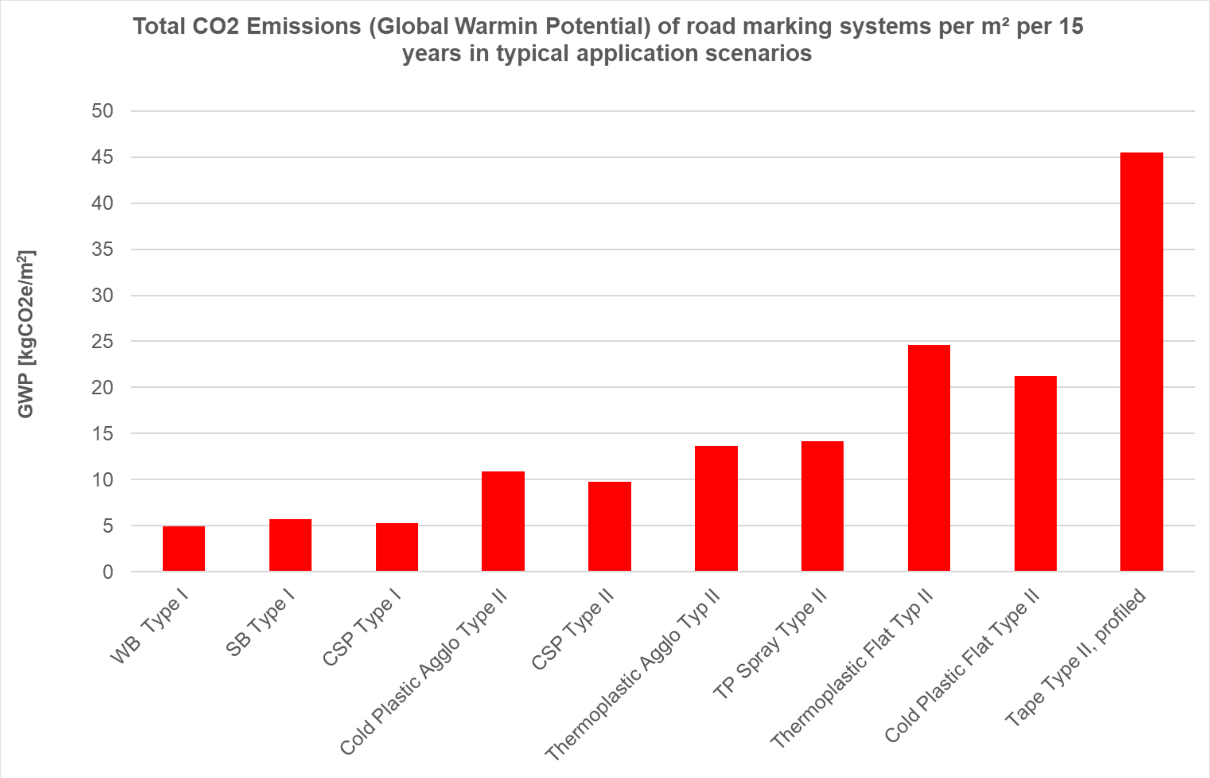


Figure 4: Total CO2 emissions per square meter over 15 years for different road marking systems in their typical application scenario.

Results for spray applied systems in a medium to high traffic scenario with an average daily traffic load of 10000 to 15000 cars per day are given in figure 5. This allows a comparison with the aforementioned study by Evonik in 2011 that assumed more frequent renewal, respectively intervention at 100 % of minimum retro-reflectivity in use phase but was conducted for an evaluation period of 10 years.
A low traffic density application scenario (average daily traffic < 5000 cars per day) is analyzed in figure 6. In such secondary roads Type I spray applied road markings are typically used. Agglomerated Systems (Type II thermoplastic or cold plastic) are only occasionally used at accident hotspots for instance. Under such low traffic wear such systems can easily provide Type I retro-reflectivity for 15 years.

Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

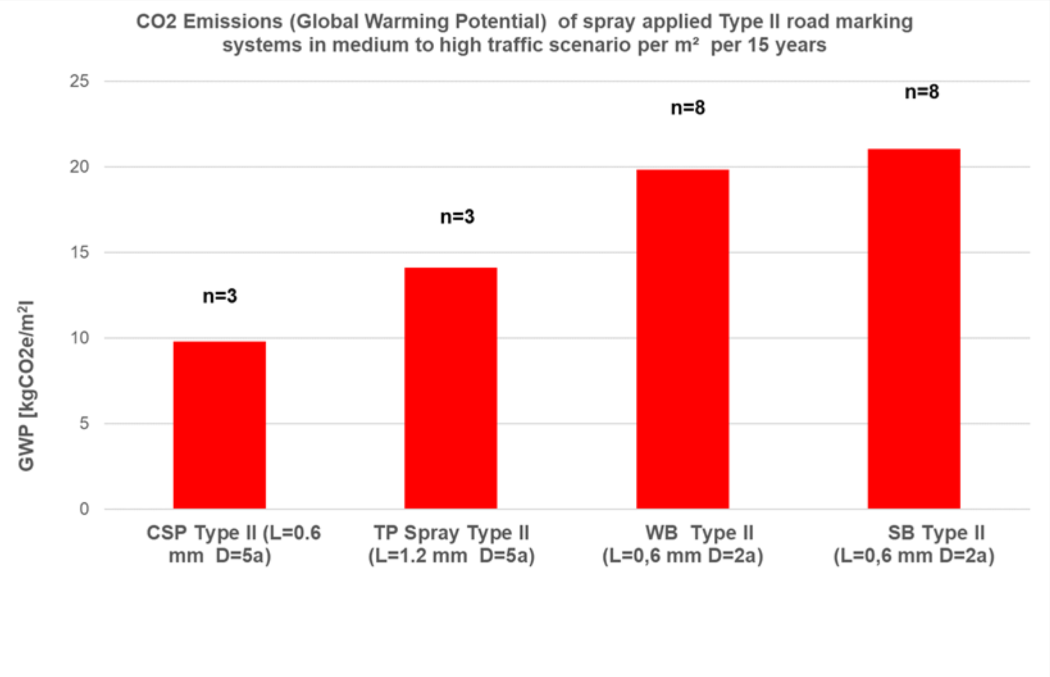


Figure 5: Total CO2 emissions of spray applied road marking systems with wet film layer thickness L per square meter over 15 years in a medium traffic wear scenario with functional durability D (n= number of applications within 15 years).

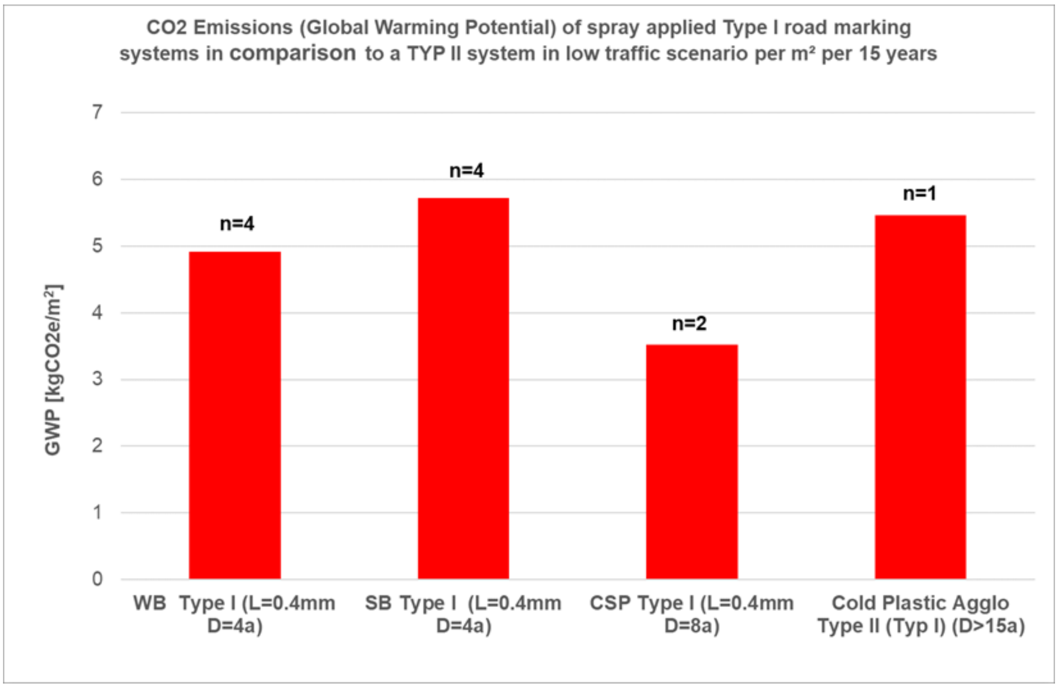


Figure 6: Figure 6: Total CO2 emissions of spray applied Type I and an agglomerated cold spray plastic TYP II road marking systems per square meter over 15 years in a low traffic wear scenario (D= functional durability; L= wet film layer thickness; n= number of applications within 15 years).

Deutsche Studiengesellschaft für
Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

Results:
Qualitative results of the former (Evonik) study are largely confirmed by the current reevaluation (see figure 1 and figure 5), although more frequent renewal due to strict intervention at 100% threshold as assumed by Evonik requires more resources with higher absolute CO2 emissions cradle-to-grave.
Both components of the road marking system, namely material and drop-on glass beads contribute significantly to the cradle-to gate CO2 emissions. For hot applied thermoplastic systems contribution from application need to be considered as well.
In-use durability of the road marking system at typical traffic wear conditions are most decisive for the overall (cradle-to-gate) CO2 emissions.
If applied on roads with elevated traffic density water-born or solvent-born paints require much more frequent renewal and rather high amount of material and glass bead consumption in total over 15 years, when compared to durable systems. Cold plastic or thermoplastic systems are more resource-efficient and provide lower environmental impact and less CO2 emissions to maintain road markings on roads with elevated traffic density.
However, on secondary roads with low traffic density scenarios paint systems can be an CO2-efficient option (see figure 6).

Conclusions / Recommendations
Only officially approved road marking systems are to be used according to the specified traffic class. Life cycle calculation shall be based on the system composition and material and drop on glass bead amount per square meter as specified.
A generic sample EPD within a given material technology (e. g. waterborne paint, solvent-borne paint, cold plastic, thermoplastic or tape) shall be constructed for the worst-case scenario of the system compositions.

Functional unit: Environmental impacts per square meter marked area.
Evaluation range: Cradle-to-grave impacts shall be evaluated over a realistic period (e.g.15 years) representing the average lifespan of a pavement.

Scope of the impact evaluation has to be cradle-to grave to allow the comparison of different material technologies.
Road markings systems, material and drop-on beads need to be considered.
Transports to the jobsite plays a minor role.
Application needs to be considered (e. g. heating systems for hot applied thermos, or thin layer refreshment technologies for agglomerates).
Disposal of road markings can be neglected since old road markings are grounded off an reused in road-construction.
Cradle-to-gate emissions of materials and drop-on beads and application are not sufficient to assess environmental impacts of a road marking system over the whole life cycle.
Use phase and in use-durability of the system is decisive for the overall CO2 emissions.
Cradle-to-grave emissions of the various material technologies shall be evaluated in relevant traffic scenarios as established in table 1 or 3.
Cradle-to-grave emissions shall be calculated based on the representative in-use-durability for a given material technology as specified in table 1 or figure 5 and figure 6.

Deutsche Studiengesellschaft für
Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

Appendix

Empirical data on functional durability of tapes

A1: Test results federal road B4, Germany
German test field at federal road B4 at Torfhaus located in the Harz mountains offers the possibility to monitor performance of road marking systems under both traffic of 8000 vehicles per day on average and snowplow abrasion. Evaluation of 187 different road markings systems including all relevant material technologies (commercial as well as experimental systems) applied 2006 and 2007 revealed the following Bericht Straßenprüffeld im Oberharz (dsgs.de):
Paints cannot withstand such abrasion conditions more durable systems, such as cold plastic or tapes or thermoplastic that are clearly visible for many years.
Profiled tapes, agglomerated cold plastics and agglomerated thermoplastics performed up to 5 years under such harsh abrasion conditions.

Table A1: Functional durability of profiled tapes, agglomerated cold plastics and agglomerated thermoplastics after 5 years in service at German test field at federal highway B4 – Systems with min 2 years functional durability

Funktional Durability (RL_f >25)	Number of Profiled Tapes	Number of Agglomerated Cold Plastics	Number of Agglomerated Thermo Plastics
2 Years	3	3	2
3 Years	0	10	3
4 Years	0	3	0
5 Years	1	3	1
Average: 3,0 Years	2,8 Years	3,3 Years	3,0 Years

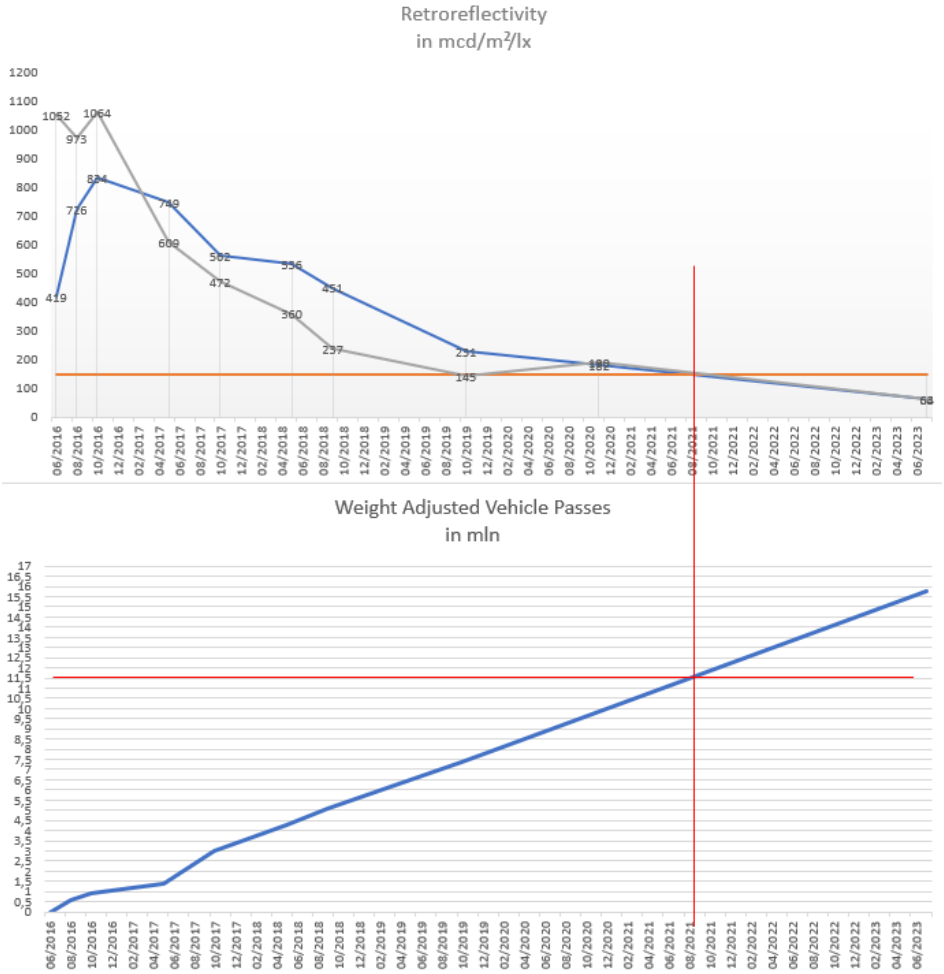
Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de

A2: Test results Croatia

A road test with two commercial profiled Type II preformed road marking tapes has been conducted at Buševec, Croatia, on national road D30. Transvers lines have been installed at the approaches to pedestrian crossings at this road bearing an average daily traffic of 7736 vehicles per day including 653 trucks of >3.5 tons according to Croatian Roads. Retro-reflectivity of the tapes and accumulated weight average traffic (see ONR 22440-1) versus time in service is displayed in figure A1. According to this data for instance, retro-reflectivity of tape installed in June 2016 with initial retro-reflectivity RL = 834 mcd/m²/lx dropped to RL= 64 mcd/m²/lx only after 7 years [Swarco Road Marking Systems; private communication February 15th, 2024].

Figure A1: Retroreflectivity RL of two profiled preformed road marking tapes and accumulated weight average traffic versus time in service at national road D30 in Croatia.



Deutsche Studiengesellschaft für Straßenmarkierungen e.V. (DSGS)
Wiedaer Straße 22
37441 Bad Sachsa

Telefon: 05523 / 999980
Telefax: 05523 / 999925
E-Mail: info@dsgs.de
Internet: www.DSGS.de