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Revision of the EU Ecolabel criteria for Indoor and Outdoor Paints and Varnishes

Draft Preliminary Report v1.0

Pérez-Camacho, M. N., Wolf, O. (JRC Dir. B - Fair and Sustainable Economy)

Rames, M., Donatello, S., Rück, L, Guimarães, R., Jordão, M. C, Anthonisen, S. (Viegand Maagøe)

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Joint Research Centre

Contact information [optional element]
Name:
Address:
Email:
Tel.:

EU Science Hub
https://joint-research-centre.ec.europa.eu

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Abstract

This Preliminary Report is intended to provide the background information for the revision of the existing EU Ecolabel criteria for indoor and outdoor paints and varnishes (Commission Decision 2014/312/EU). The present study has been carried out by the Joint Research Centre (JRC) with the technical support of Viegand Maagøe. The work is being developed for the European Commission's Directorate General for the Environment.

The EU Ecolabel criteria for indoor and outdoor paints and varnishes set out in Decision 2014/312/EU were established in 2014. Commission Decision (EU) 2022/1229 prolonged their validity until 31 December 2025.

To support the revision process with technical evidence, this Preliminary Report consists of:

— an analysis of the scope, definitions and description of the legal framework, as well as a first proposal for the revised scope (Task 1);

— a market analysis (Task 2);

— a technical analysis, including an environmental assessment (Task 3).

This background information, combined with input received from the stakeholders involved, will be used in the revision process to justify the choices behind the revision of the criteria.

This Preliminary Report is delivered at the same time as the Draft Technical Report 1 and both will be used as the background information required for the first Ad-hoc Working Group (AHWG) meeting, scheduled to take place on the 8 May 2024.

Executive summary

This Preliminary Report provides the initial input for the revision of the EU Ecolabel criteria for indoor and outdoor paints and varnishes. This report includes an analysis of the scope and definitions of the product group under revision, a market analysis at global and EU level, and a technical analysis, in which a literature review was carried out and an environmental impact assessment was conducted using the PEF methodology.

Policy context

The EU Ecolabel is the official voluntary labelling scheme of the EU that promotes the production and consumption of products (goods and services) with a reduced environmental impact over their life cycle, and is aimed at products with a high level of environmental performance. Established in 1992, it has become a key policy instrument within the European Commission's Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan (see COM(2008) 397[1]) and the Roadmap for a Resource-Efficient Europe (see COM/2011/0571[2]). The Roadmap was designed to move the economy of Europe onto a more resource-efficient path by 2020 in order to become more competitive and to create growth and employment.

The EU Ecolabel also has links with other policy instruments, such as Green Public Procurement (GPP, see COM(2008) 400[3]), the Eco-Management and Audit Scheme (EMAS) (see Regulation (EC) No 1221/2009[4] and Regulation (EU) No 2018/2026[5]) and the Ecodesign Directive (see Directive 2009/125/EC[6]).

The EU Ecolabel was mentioned as having an important role in the new Circular Economy Action Plan (CEAP) from March 2020[7].

The EU Ecolabel was also mentioned in the Chapeau Communication on making sustainable products the norm. This Communication accompanies a package of measures proposed in the CEAP and adopted on 30 March 2022, including: a proposal for the Ecodesign for Sustainable Products Regulation[8], an EU strategy for sustainable and circular textiles, a proposal for a revised Construction Products Regulation, and a proposal for empowering consumers in the green transition. The Communication mentions the EU Ecolabel as an important tool whose criteria will be developed in synergy with future Ecodesign measures.

Main findings

The assessment of the scope and definitions revealed that there are many different potential technical categories of indoor and outdoor paint and varnish products, which do not complement each other well. In addition, stakeholders are not interested in an expansion to the scope and definitions of the product group under revision. The market analysis concluded that the demand for coatings by value was dominated by the Asia Pacific region, followed by Europe and North America. The raw materials constitute most of the production costs for manufacturers of paints and varnishes (40-60%). The literature review revealed a gap between the recognized concerns associated with paints and varnishes and their integration into LCA research. Despite this, the review encountered challenges stemming from the absence of standardized information and limited availability of Life Cycle Assessment (LCA) analyses for paints and varnishes. Moreover, difficulties in comparing paint formulations were noted due to variations in ingredient details and percentages. Additional hurdles included inconsistent use of function units (e.g., 1 m^2, 1 kg) across studies and a lack of approaches. However, despite these obstacles, the reviewed studies consistently emphasized the noteworthy impact of global warming potential (GWP) and emissions related to human toxicity during both production and application phases. The LCA screenings of indoor and outdoor paints and varnishes identified environmental hotspots in the production of raw materials, in particular binders and pigments, followed by the application of the coatings on the substrates. A sensitivity analysis on preservation including and excluding biocides revealed a better environmental performance for paints containing biocides.

[1] See: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0397:FIN:en:PDF
[2] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52011DC0571
[3] See: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0400:FIN:EN:pdf
[4] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009R1221
[5] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R2026
[6] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0125
[7] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN
[8] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022PC0142

Related and future JRC work

This Preliminary Report effectively constitutes supporting background research and context for the proposal of revised EU Ecolabel criteria for indoor and outdoor paints and varnishes, which will be presented in a series of draft JRC Technical Reports over the next 12-18 months, culminating in a final version of revised criteria to be adopted.

1 Introduction

The objective of this project[9] is to revise the existing EU Ecolabel criteria for indoor and outdoor paint and varnishes (Commission Decision (EU) 2014/312[10]) according to the revision process laid down in the Ecolabel Regulation[11]. The current EU Ecolabel criteria for the indoor and outdoor paints and varnishes product group were adopted in 2014 and are valid until the 31 December 2025.

The EU Ecolabel is the official voluntary labelling scheme of the EU that promotes the production and consumption of products (goods and services) with a reduced environmental impact over their life cycle, helping to define and signal products with a high level of environmental performance.

This Preliminary Report is structured as follows:

- Task 1: Scope and definitions. This chapter[12] focuses on the identification of relevant background information related to scope and definitions. It includes summarised information on product definitions, mentions relevant technical standards, EU policy and legislation, and presents stakeholders' views on scope and definitions (via a preliminary stakeholder questionnaire exercise).
- Task 2: Market analysis. This chapter focuses on the European market for paints and varnishes. The task report starts by describing the production value chain for these products and then presents the main actors and sales trends and forecasts at global level. A much closer look is then made into data at EU level, including a presentation of qualitative and quantitative market trends in the paints and varnish market, and in the uptake of the EU Ecolabel in the sector.
- Task 3: Technical analysis. This chapter provides technical information on paints and varnishes related to manufacturing processes, and environmental and health issues. The analysis describes the paint and varnish manufacturing and role of the different raw materials in the product. Then it addresses the environmental impacts through 1) an LCA (Life Cycle Assessment) literature review, and then by performing a screening LCA study, according to the existing PEFCR for decorative paints. Because the LCA results are not directly relatable to health issues, the report therefore looks into the presence in paints and varnishes of chemicals of potential concern in terms of environmental and human hazard, based on the CEPE Ingredients list[13] and the ECHA database. A special focus is put on preservatives, titanium dioxide and VOCs (Volatile Organic Compounds). Finally, some indicative improvement potentials and best practices are listed.

9 See: Documentation relating to the EU Ecolabel paint and varnish criteria revision process can be found on the JRC website here: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/461/documents.

10 See: https://eur-lex.europa.eu/eli/dec/2014/312/2022-07-18

11 See: Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel (OJ L 27, 30.1.2010, p. 1–19).

12 See: Documentation relating to the EU Ecolabel paint and varnish criteria revision process can be found on the JRC website here: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/461/documents

13 See: https://lcdn-cepe.org/processList.xhtml?stock=EF_3_1_logical_datastock

2 Task 1: Scope and definition analysis

The aim of task 1 of this Preliminary Report is to provide background information supporting the revision of the current scope and definitions included in the EU Ecolabel criteria for indoor and outdoor paints and varnishes. It includes summarised information on product categories and definitions, mentions relevant technical standards, EU policy and legislation, and presents stakeholders' views on scope and definitions (*via* a preliminary stakeholder questionnaire exercise).

This chapter starts by providing background to the existing scope and definitions of current EU Ecolabel criteria in force, to then compare them against definitions used in statistical sources, technical standards, relevant legislation and other ecolabels. Specifically, the report covers:

- The categories directly defined in Decision 2014/312/EU for EU Ecolabel for indoor and outdoor paints and varnishes.
- Statistical categories defined in the Eurostat PRODCOM database and EU Ecolabel license data.
- Technical categories defined by CEN/TC 139 and relevant EN standards under their mandate.
- A summary of relevant EN, ISO and EN ISO standards.
- Relevant EU legislation for paint and varnish products, including broader legislative acts that affect paint and varnish producers, but also many other sectors.
- Inputs from the preliminary stakeholder questionnaire

While the exact difference between "statistical" categories and "technical" categories is open to interpretation, for the purposes of this task, we have treated "statistical" categories as those that are used in market data (especially in the PRODCOM database) while "technical" categories are considered as those defined in technical standards.

Ideally, the terminology and categorisation should be the same for all legislation and standards, but this is often not the case, as the evolution of these aspects only rarely takes place in a synchronised manner. This is also the case for paints and varnishes, where products are grouped by different criteria and definitions, as elaborated in the next sections.

This section also briefly summarises relevant results of preliminary questionnaire to incorporate stakeholder feedback into revised proposals for scopes and definitions. Ultimately, it describes, discusses, and highlights any potential modification to current scope and definitions based on the previous aspects, as well as on legal, policy and technical frameworks.

2.1 Categories as defined in Decision 2014/312/EU for EU Ecolabel paints and varnishes (existing scope and definition)

From reading the criteria in Decision 2014/312/EU, it is clear that the scope for EU Ecolabel has been matched with that of Directive 2004/42/CE to a large extent. The scope of the EU Ecolabel states:

"*1. The product group of 'indoor and outdoor paints and varnishes' shall comprise indoor and outdoor decorative paints and varnishes, woodstains and related products intended for use by consumers and professional users falling under the scope of Directive 2004/42/CE of the European Parliament and of the Council.*

2. The product group of 'indoor and outdoor paints and varnishes' shall comprise: floor coatings and floor paints; paint products which are tinted by distributors at the request of consumer (non-professional) or professional decorators, tinting systems, decorative paints in liquid or paste formulas which may have been pre-conditioned, tinted or prepared by the manufacturer to meet consumer's needs, including wood paints, wood and decking stains, masonry coatings and metal finishes primers and undercoats of such product systems as defined in Annex I to Directive 2004/42/CE."

The purpose of Directive 2004/42/CE is to set legally mandatory VOC content limits for different categories of paint and varnish products. The EU Ecolabel criteria align perfectly with terms and definitions of Directive 2004/42/CE in criterion 4 about VOC limits (except that the EU Ecolabel also adds one more category called "anti-rust paints"). But other terms are also used where the EU Ecolabel has additional criteria, which differ depending on which type of paint is being referred to. Consequently, it is useful to cross-check the paint and varnish categories defined in Directive 2004/42/CE against the terms used in the paint and varnish EU Ecolabel criteria.

Table 1. Different paint and varnish product categories covered by the EU Ecolabel.

EU Ecolabel terminology	Equivalent categories (defined in Annex I to Directive 2004/42/EC)
Indoor wall and ceiling	(a) 'matt coatings for interior walls and ceilings' means coatings designed for application to indoor walls and ceilings with a degree of gloss ≤ 25@60°.
	(b) 'glossy coatings for interior walls and ceilings' means coatings designed for application to indoor walls and ceilings with a degree of gloss > 25@60°.
Outdoor for masonry	(c) 'coatings for exterior walls of mineral substrate' means coatings designed for application to outdoor walls of masonry, brick or stucco;
Trim and cladding	(d) 'interior/exterior trim and cladding paints for wood, metal or plastic' means coatings designed for application to trim and cladding which produce an opaque film. These coatings are designed for either a wood, metal or a plastic substrate. This subcategory includes undercoats and intermediate coatings;
Varnish and woodstain	(e) 'interior/exterior trim varnishes and woodstains' means coatings designed for application to trim which produce a transparent or semi-transparent film for decoration and protection of wood, metal and plastics. This subcategory includes opaque woodstains. Opaque woodstains means coatings producing an opaque film for the decoration and protection of wood, against weathering, as defined in EN 927-1, within the semi-stable category;
	(f) 'minimal build woodstains' means woodstains which, in accordance with EN 927-1:1996, have a mean thickness of less than 5µm when tested according to ISO 2808: 1997, method 5A;
Primer	(g) 'primers' means coatings with sealing and/or blocking properties designed for use on wood or walls and ceilings;
Undercoat and primer	(h) 'binding primers' means coatings designed to stabilise loose substrate particles or impart hydrophobic properties and/or to protect wood against blue stain;
One pack performance and floor covering paint	(i) 'one-pack performance coatings' means performance coatings based on film-forming material. They are designed for applications requiring a special performance, such as primer and topcoats for plastics, primer coat for ferrous substrates, primer coat for reactive metals such as zinc and aluminium, anticorrosion finishes, floor coatings, including for wood and cement floors, graffiti resistance, flame retardant, and hygiene standards in the food or drink industry or health services;
Two-pack reactive performance coatings for specific end use such as floors	(j) 'two-pack performance coatings' means coatings with the same use as one-performance coatings, but with a second component (e.g. tertiary amines) added prior to application;
Thick decorative coating (indoor and outdoor)	(l) 'decorative effect coatings' means coatings designed to give special aesthetic effects over specially prepared pre-painted substrates or base coats and subsequently treated with various tools during the drying period.
Anti-rust paints (no definition)	No definition provided in Decision 2014/312/EU

Source: Own elaboration using information from Decision 2014/312/EU and Directive 2004/42/EC.

While most of the terms used in the EU Ecolabel criteria can be quite easily matched to corresponding definitions in Directive 2004/42/CE, there are some areas that do not match up and require further clarification. For example:

— Directive 2004/42 mentions "(k) multicoloured coatings" and provides a definition as: "*[…] means coatings designed to give a two-tone or multiple-colour effect, directly from the primary application*". However, this type of paint is not referred to at all in the EU Ecolabel legal text, even though it is technically in the scope.

— Conversely, the EU Ecolabel criteria mention "Anti-rust paints", but these are not mentioned as a standalone category of paint in Directive 2004/42/CE. The closest mention to this category of paint is as one of several types of coating included under the definition of "one pack performance and floor covering paint", which makes mention of "*[…] primer coat for reactive metals such as zinc and aluminium, anticorrosion finishes […]*".

- The term "lasure" is used in EU Ecolabel criteria and defined there as well as "*coatings producing a transparent or semi-transparent film for decoration and protection of wood against weathering, which enables maintenance to be carried out easily*", the term is only used to exempt certain products from requirements and has no specific VOC content limit, so no problem with this additional term being used.
- There is a definition of "*two-pack performance*" coatings in Directive 2004/42/CE and a VOC limit for these products in criterion 4 of the EU Ecolabel criteria. However, no mention of these paints is made elsewhere in the EU Ecolabel criteria and it is unclear which performance requirements apply to these paints in criterion 3 of the EU Ecolabel. It is to be checked with expert stakeholders which types of paint and varnish would include the use of two-pack formulations.

In order to help to understand which products are in the scope and which criteria apply to which specific types of products a table that indicates which criteria apply to which category or categories of paint and varnish products is included in the Draft Technical Report 1.

2.2 Statistical categories for paints and varnishes

A search in the Eurostat PRODCOM database for products categories containing the word "paint" or "varnish", revealed a number of categories that are directly relevant to the EU Ecolabel scope, plus other categories that provide some insight into upstream parts of the production value chain.

As seen in the table below, the PRODCOM codes are very much defined by the coating chemistry and solvents used. However, it is not so easy to define the extent to which these categories are covered by the EU Ecolabel because the scope of the EU Ecolabel is defined in a different way, being based on the application (e.g. floor, wall, interior etc.) and properties of the final coating (e.g. matt, glossy etc.), rather than the chemistry of the formulation. The two main PRODCOM codes are nonetheless 20301150 and 20301170.

Table 2. Potentially relevant statistical categories related to paints and varnishes in the PRODCOM database. Colour scheme: red: not included, green: included and yellow: depends on the application.

PRODCOM code	Description	Currently in scope of EU Ecolabel paints and varnishes?
16103116	Wood tar; wood tar oils; wood creosote; wood naphtha; vegetable pitch; brewers' pitch and similar preparations based on rosin, resin acids or on vegetable pitch	No, expressly excluded in the existing criteria as preservation products for wood impregnation.
20301150	Paints and varnishes, based on acrylic or vinyl polymers dispersed or dissolved in an aqueous medium (including enamels and lacquers)	Yes, these emulsion paints (water-based) are generally in the scope although exceptions may exist depending on the specific application they are designed for.
20301170	Other paints, varnishes dispersed or dissolved in an aqueous medium	
20301225	Paints and varnishes, based on polyesters dispersed/dissolved in a non-aqueous medium, weight of the solvent > 50 % of the weight of the solution including enamels and lacquers	Probably not, because they are not water-based.
20301229	Paints and varnishes, based on polyesters dispersed/dissolved in a non-aqueous medium including enamels and lacquers excluding weight of the solvent > 50 % of the weight of the solution	
20301230	Paints and varnishes, based on acrylic or vinyl polymers dispersed/dissolved in non-aqueous medium, weight of the solvent > 50 % of the solution weight including enamels and lacquers	Probably not, because they are not water-based.
20301250	Other paints and varnishes based on acrylic or vinyl polymers	In theory yes, but depends on the intended application.
20301270	Paints and varnishes: solutions n.e.c.	In theory yes, but depends on the intended application.
20301290	Other paints and varnishes based on synthetic polymers n.e.c.	In theory yes, but depends on details. Supposedly this is where certain floor paint, furniture paint and radiator paint

PRODCOM code	Description	Currently in scope of EU Ecolabel paints and varnishes?
		chemistries would lie, for example polyurethane based formulations.
20302213	Oil paints and varnishes (including enamels and lacquers)	Oil paints not covered since not covered by Directive 2004/42/EC. But varnishes might be included if they are not oil-based and comply with EU Ecolabel VOC limits.
20302350	Artists', students', or signboard painters' colours, amusement colours and modifying tints in sets of tablets, tubes, jars, bottles or pans	Not included.
20302370	Artists', students' or signboard painters' colours, amusement colours and modifying tints in tablets, tubes, jars, bottles or pans (excluding in sets)	Not included.
20302215	Prepared water pigments for finishing leather; paints and varnishes (including enamels, lacquers and distempers) (excluding of oil)	Not as a standalone product, but clearly an important upstream material used in formulations.
20302240	Pigments, including metallic powders and flakes, dispersed in non-aqueous media, in liquid or paste form, of a kind used in the manufacture of paints; colorants and other colouring matter, n.e.c. put up for retail sale	Not as a standalone product, but clearly an important upstream material used in formulations.

Source: Own elaboration adapted from PRODCOM database.

2.3 Technical categories of paints and varnishes and relevant standards

As per the definitions in Directive 2004/42/CE, in Decision 2014/312 and in the cross-check with PRODCOM categories, it is clear that the EU Ecolabel criteria consider at least 7 main different categories of indoor and outdoor paint or varnish products. This section shows the different technical categories defined in relevant international standards and compares to those categories in the current EU Ecolabel criteria.

In the EU, these standards for paints and varnishes are under the responsibility of CEN/TC 139 while the ISO/TC 35 is the International Organisation for Standardisation Technical Committee for Paints and Varnishes. The technical committees are further split into the working groups and related standards mentioned in Table 3[14]. The table lists the main technical standards that apply to paints and varnishes, and the standards especially relevant for identifying technical categories are highlighted. These highlighted standards are then further elaborated in the sub-sections of this chapter, focusing especially on the scope and definitions they apply.

Table 3. Main structure of CEN/TC 139 and related scope and standards.

Working Group	Scope	Relevant EN standards
1 (AFNOR)	Coatings and related materials for the preservation, decoration and protection of interior and exterior new and old, coated and uncoated mineral building materials, including organic binders renderings and thermal insulation systems; classification,	EN 1062: Paints and varnishes - Coating materials and coating systems for exterior masonry and concrete 1062-1.: Part 1: Classification. 1062-6: Part 6: Determination of carbon dioxide permeability. 1062-7: Part 7: Determination of crack bridging properties. 1062-11: Part 11: Methods of conditioning before testing. 13300: Paints and varnishes - Paints and varnishes for interior walls and ceilings – Classification. 16566: Paints and varnishes - Fillers for internal and/or external works - Adaptation of fillers to European standards

14 These working groups seem to be the only active ones according to the information on the CENELEC website: https://standards.cencenelec.eu/dyn/www/f?p=205:29:0::::FSP_ORG_ID,FSP_LANG_ID:6121,25&cs=1C7505C79C3E35AE9B8F4DD4BE9C3E353#1

Working Group	Scope	Relevant EN standards
	methods of test and performance specifications.	
2 (DIN)	Coating systems for the protection and decoration of wood used in buildings; classification, test methods and performance specifications.	EN 927: Paints and varnishes - Coating materials and coating systems for exterior wood 927-1: Part 1: Classification and selection 927-2: Part 2: Performance specification 927-3: Part 3: Natural weathering test 927-5: Part 5: Assessment of the liquid water permeability 927-6: Part 6: Exposure of wood coatings to artificial weathering using fluorescent UV lamps and water 927-7: Part 7: Assessment of knot staining resistance of wood coatings 927-8: Part 8: Determination of the adhesion on wood after water exposure by a double-X-cut test 927-9: Part 9: Determination of pull-off strength 927-10: Part 10: Resistance to blocking of paints and varnishes on wood 927-11: Part 11: Assessment of air inclusions/microfoam in coating films 927-12: Part 12: Ultraviolet and visible radiation transmittance 927-13: Part 13: Assessment of resistance to impact of a coating on a wooden substrate 927-14: Part 14: Determination of tensile properties of coating films prCEN/TS 927-15: Part 15: Assessment of tannin staining using water immersion CEN/TS 16360: Paints and varnishes - Coating materials and coating systems for exterior wood - Assessment of film extensibility by indentation of a coating on a wooden substrate CEN/TS 16498: Paints and varnishes - Coating materials and coating systems for exterior wood - Assessment of tannin staining CEN/TS 16969: Paints and varnishes - Coating materials and coating systems for exterior wood - Assessment of end grain sealing performance
9 (DIN)	Preparation of standards dealing with the test methods for continuously organic coated coil and flat sheet metals	Not considered relevant to the EU Ecolabel scope, but main standards are: EN 13523: Coil coated metals - Test methods EN 16074: Paints and varnishes - Determination of non-volatile-matter content and spreading rate of coil coating materials
10 (DIN)	Preparation of standards for the determination of leaching of substances from coatings and for the determination of efficacy of film preservatives.	Not relevant to the scope and definitions of EU Ecolabel criteria, but are relevant to specific EU Ecolabel criteria. EN ISO 7012: Paints and varnishes — Determination of preservatives in water-dilutable coating materials pr7012-1: Part 1: Determination of in-can free formaldehyde pr7012-2: Part 2: Determination of in-can total formaldehyde pr7012-3: Part 3: Determination of in-can isothiazolinones with LC/UV and LC-MS-MS EN 15457.: Paints and varnishes - Laboratory method for testing the efficacy of film preservatives in a coating against fungi EN 15458: Paints and varnishes - Laboratory method for testing the efficacy of film preservatives in a coating against algae EN 16105: Paints and varnishes - Laboratory method for determination of release of regulated dangerous substances from coatings in intermittent contact with water
13 (BSI)	Preparation of standards for reactive coatings in end use conditions. The standards cover the reactive coating alone or in	Not considered relevant to the EU Ecolabel scope, but main standard is: EN 16623: Paints and varnishes - Reactive coatings for fire protection of metallic substrates - Definitions, requirements, characteristics and marking

Working Group	Scope	Relevant EN standards
	conjunction with primers and top-coats and if applicable reinforcement systems. This Standards set out the performance criteria, the verification methods used to examine the various aspects of performance, the assessment criteria used to judge the performance for the intended use and the presumed conditions for the design and execution of the reactive coating in the works.	

Source: Own elaboration based on CEN/TC 139

Other CEN/TC 139 working groups were also identified[15], but did not seem to be active. They included: WG4 – Terminology; WG5 – Organic coatings on aluminium for architectural purposes; WG7 – Paints and varnishes for wood furniture; WG8 – Powder organic coatings for hot-dip galvanised steel products and WG13 – Reactive coatings for fire protection. None of these were considered as directly relevant to EU Ecolabel paints and varnishes at first glance.

Focusing on WGs 1, 2 and 10, there are around 30 EN product standards that can be considered as being highly relevant to the current scope of EU Ecolabel paints and varnishes and that are currently in force or under development.

Other standards being developed from ISO/TC 35 are ISO/DIS 11908 for Binders for paints and varnishes — Amino resins — General methods of test; ISO/CD 15715 Binders for paints and varnishes — Determination of turbidity and ISO/AWI 24959 Paints and Varnishes — Competency requirements of coating inspectors from where ISO/TC 35/SC 9 for General test methods for paints and varnishes which could be identified as relevant at a later stage of the revision process.

There are also a number of other standards that are relevant since they are mentioned directly in the EU Ecolabel criteria in Decision 2014/312/EU. However, it seems that many of these standards have been withdrawn or been superseded by other standards. A summary of the relevant standards is provided in the table below.

[15] See: As per information on this website: https://standards.iteh.ai/catalog/tc/cen/2fc460be-2fd3-4604-9b01-dd9f706c943f/cen-tc-139

Table 4. Different paint and varnish product categories covered by the EU Ecolabel.

Criteria for awarding the EU Ecolabel to paints and varnishes:	**Standards applied**	**Title (standard type, year of latest version)**
(1) White pigment and wet scrub resistance	Wet scrub: EN 13300	Paints and varnishes – Paints and varnishes for interior walls and ceilings – Classification (ISO, 2022)
	Wet scrub: EN ISO 11998.	Paints and varnishes — Determination of wet-scrub resistance and cleanability of coatings (ISO, 2006)
(2) Titanium dioxide	Not applicable	
(3) Efficiency in use		
(a) Spreading rate	ISO 6504/1	Paints and varnishes — Determination of hiding power Part 1: Kubelka-Munk method for white and light-coloured paints (ISO, 2019)
(b) Resistance to water	ISO 2812-3	Paints and varnishes. Determination of resistance to liquids Method using an absorbent medium (EN ISO, 2019)
(c) Adhesion	EN 24624	Paints and varnishes. Adhesion testing [ISO,1995- Withdrawn]
	EN 2409	Paints and varnishes — Cross-cut test (ISO, 2020)
(d) Abrasion	EN ISO 7784-2	Paints and varnishes — Determination of resistance to abrasion Part 2: Method with abrasive rubber wheels and rotating test specimen (ISO, 2023)
(e) Weathering	EN 11507	Paints and varnishes — Exposure of coatings to artificial weathering — Exposure to fluorescent UV lamps and water [ISO, 2007-Withdrawn]
	EN 927-6	Paints and varnishes - Coating materials and systems for outdoor wood - Part 6: Artificial weathering of wood coatings with fluorescent UV lamps and water (ISO, 2018)
	ISO 7724-3	Paints and varnishes — Colorimetry Part 3: Method with abrasive-paper covered wheel and linearly reciprocating test specimen (ISO, 2022)
	ISO 2813	Paints and varnishes — Determination of gloss value at 20°, 60° and 85° (ISO, 2014)
	EN ISO 4628-2 (Parts 2, 4, 5 and 6)	Paints and varnishes. — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance Part 2: Assessment of degree of blistering (ISO, 2016) Part 4: Assessment of degree of cracking (ISO, 2016) Part 5: Assessment of degree of flaking (ISO, 2022) Part 6: Assessment of degree of chalking by tape method (ISO, 2011)

Criteria for awarding the EU Ecolabel to paints and varnishes:	Standards applied	Title (standard type, year of latest version)
(f) Water vapour permeability	EN ISO 7783	Paints and varnishes — Determination of water-vapour transmission properties — Cup method (ISO, 2018)
	EN1062-1	Paints and varnishes. Painting materials and systems for surface treatment of external masonry and concrete. Part 1: Classification [ISO,1997-Withdrawn]
(g) Liquid water permeability	EN 1062-3	Paints and varnishes - Coating materials and systems for external masonry and concrete Part 3: Determination of water permeability (ISO,2008)
(h) Fungal resistance	EN 15457	Paints and varnishes – Laboratory method for testing the efficacy of film preservatives in a coating against fungi [ISO,2014-Withdrawn]
	EN 15458	Paints and varnishes - Laboratory method for testing the effectiveness of film protection in coatings against algae [ISO,2014-Withdrawn]
(i) Crack bridging	EN 1062-7	Paints and varnishes - Paint materials and systems for surface treatment of external masonry and concrete - Part 7: Determination of fracture properties (ISO, 2004)
(j) Alkali resistance	ISO 2812-4	Paints and varnishes. Determination of resistance to liquids Spotting methods (EN ISO, 2017)
(k) Corrosion resistance	EN ISO 12944 (Parts 2 and 6)	Paints and varnishes — Corrosion protection of steel structures by protective paint systems Part 2: Classification of environments (ISO, 2017) Part 6: Laboratory performance test methods (ISO, 2018)
	ISO 9227	Mentioned near the bottom of Table 2 of Decision 2014/312/EU but appears to be a typo since ISO 9227 is about cranes, while there is an EN 927 standard.
	ISO 4628 (Parts 2 and 3)	Paints and varnishes. — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance Part 2: Assessment of degree of blistering (ISO, 2016) Part 3: Assessment of degree of rusting (ISO, 2016)
(4) Volatile and Semi-volatile Organic Compounds (VOCs, SVOCs)	ISO 11890-2	Paints and varnishes — Determination of volatile organic compound (VOC) content Part 2: Gas-chromatographic method (ISO, 2020)
	ISO 17895	Paints and varnishes — Determination of the volatile organic compound content of low-VOC emulsion paints (in-can VOC) (ISO, 2005)

Criteria for awarding the EU Ecolabel to paints and varnishes:	Standards applied	Title (standard type, year of latest version)
(5) Restriction of hazardous substances and mixtures		
Overall restrictions that apply to hazard classifications and risk phrases	Not applicable	
Restrictions that apply to Substances of Very High Concern	Not applicable	
Restrictions that apply to specific hazardous substances	Not applicable	
(6) Consumer information	Not applicable	
(7) Information appearing on the EU Ecolabel	Not applicable	

Source: Own elaboration

There are 30 performance related standards already mentioned in the EU Ecolabel criteria and also the French standard (NF T30-073) “Paints and varnishes – Assessment of the natural spreading rate”.

The standards managed by CEN/TC 139 highlighted in blue in Table 3 that are relevant for defining “technical categories” of paint and varnish products (namely EN 1062-1, EN 13300, EN 927-1 and EN 927-2), EN ISO 4618) are worth further consideration.

2.3.1 EN 1062-1: Coating materials and coating systems for exterior masonry and concrete.

This standard “specifies a general system for the description of coating materials and coating systems for the preservation, decoration and protection of exterior new and old, coated or uncoated masonry and concrete. It also includes a classification system based on certain physical properties”. The main properties and performance classes are summarised below.

Table 5. Different product and performance categories under EN 1062 (exterior masonry and concrete coatings).

Category	Options available
Description by chemical binder	Non exhaustive list: (i) acrylic resin; (ii) alkyd resin; (iii) bitumen; (iv) cement; (v) chlorinated rubber; (vi) epoxy resin; (vii) hydraulic lime; (viii) oil; (ix) polyester; (x) silicate; (xi) silicone resin; (xii) silicone resin; (xiii) polyurethane, or (xiv) vinyl resin.
Description by state of dissolution or dispersion	Can be either: (i) Water-dilutable, or (ii) Solvent-dilutable (organic solvents)
Specular gloss	As per EN ISO 2813, can be either: (i) G1 (Gloss (or High-sheen)); (ii) G2 (Mid-sheen (or Semi-gloss, Semi-Matt or Satin)) or (iii) G3 (Matt).
Dry thickness	Can be either: (i) E1 (≤50µm); (ii) E2 (50≤100µm); E3 (100≤200µm); E4 (200≤400µm), or E5 (>400µM)
Grain size	Using either EN ISO 1524 (for fine measurement) or EN ISO 787-18 for others, can be either: (i) S1, Fine (<100µm); (ii) S2, Medium (<300µm); S3, Coarse (<1500µm), or S4, Very coarse (>1500µm)
Water vapour transmission rate	According to EN ISO 7783-2, can be either: (i) V0 (no requirement); (ii) V1 (high >150 g/m2.d or <0.14m); (iii) V2 (medium 15≤150 g/m2.d or 0.14<1.4m), or (iv) V3 (low ≤15 g/m2.d or ≥1.4m)
Liquid water permeability	According to EN 1062-3, can be either: (i) W0 (no requirement); W1 kg/(high, >0.5m2.h0.5); W2 (medium, 0.1≤0.5kg/(m2.h0.5) or W3 (low, ≤0.1kg/(m2.h0.5)
Crack bridging	According to EN 1062-7, can be either: (i) A0 (no requirement); (ii) A1 (>100µm); (iii) A2 (>250µm at 0.05 mm/min); (iv) A3 (>500µm at 0.05 mm/min); (v) A4 (>1250µm at 0.5 mm/min); (vi) A5 (>2500µm at 0.5 mm/min)

Category	Options available
Carbon dioxide permeability	According to EN 1062-6, can be either: (i) C0 (no requirement), or (ii) C1 (<5 g/(m2.d) or >50m)

Source: JRC own elaboration from EN1062

Based on the information in the table above, there are 2 chemical categories (binder and solvent) and 7 performance categories, each with multiple options therein, meaning that there are a large number of potential different technical categories of coatings just for exterior masonry and concrete.

2.3.2 EN 13300: Paints and varnishes for interior walls and ceilings.

This standard "specifies a general system for the classification of paints and varnishes for interior walls and ceilings for the decoration of new and old, coated and uncoated surfaces". The main properties and performance classes are summarised below.

Table 6. Different product and performance categories under EN 13300 (interior wall and ceiling coatings).

Category	Options available
Classification by end use	Can be either: (i) decoration, or (ii) special properties
Classification by chemical type of binder	Can be (non exhaustive list): (i) acrylic resin; (ii) vinyl resin; (iii) alkyd resin; (iv) epoxy resin; (v) hydraulic lime; (vi) cement; (vii) silicate;
Specular gloss	As per EN ISO 2813, can be either: (i) G1 (Gloss) (or High-sheen); (ii) G2a, G2b (Mid-sheen (or Semi-gloss, Semi-Matt or Satin)); (iii) G3 (Matt), or (iv) G4 (Dead Matt).
Granularity (largest grain size)	As per EN ISO 1524 (for fine) or EN ISO 787-17, can be either: (i) S1 (fine, ≤100µm); (ii) S2 (medium, 100≤300µm) or (iii) S3 (coarse, 300≤1500µm)
Wet scrub resistance	As per EN ISO 11998, this can be measured only on coatings with S1 granularity. Can be either: (i) R class 1 (≤5µm at 200 scrubs); (ii) R class 2 (5≤20µm at 200 scrubs); (iii) R class 3 (20≤70µm at 200 scrubs); R class 4 (≤70µm at 40 scrubs), or (v) R class 5 (>70µm at 40 scrubs)
Hiding power	For white or light-coloured opaque paints, and according to EN ISO 6504-3, can be either: (i) H10 class 1 (≥99.5%); H10 class 2 (98≤99.5%); H10 class 3 (95<98%), or H10 class 4 (<95%)
Cleanability	Not to be declared according to EN 13300.

Source: JRC own elaboration from EN13300

2.3.3 EN 927: Coating materials and coating systems for exterior wood.

This standard "specifies a system for the classification of coating systems and coating materials for exterior wood surfaces by categories of end use, appearance and exposure conditions. It also defines several components of a multi coat system (primer, undercoat, top coat, etc.)."

The standard considers a number of different types of performance categories, as seen in the titles of other parts of the EN 927 series of standards. Such categories include:

- Part 1: Classification and selection;
- Part 2: Performance specification
- Part 3: Natural weathering test
- Part 5: Assessment of the liquid water permeability
- Part 6: Exposure of wood coatings to artificial weathering using fluorescent UV lamps and water
- Part 7: Assessment of knot staining resistance of wood coatings

— Part 8: Determination of the adherence of paint on wood by means of a double X-cut test Part 9: Determination of pull-off strength after water exposure

— Part 10: Resistance to blocking of paints and varnishes on wood

— Part 11: Assessment of air inclusions/microfoam in coating films

— Part 12: Ultraviolet and visible radiation transmittance

— Part 13: Assessment of resistance to impact of a coating on a wooden substrate

— Part 14: Determination of tensile properties of coating films

Table 7. Different product and performance categories under EN 927-1 (classification and selection).

Category	Options available
Classification by appearance	Can be either: (i) build, (ii) hiding power or (iii) gloss
Classification by end-use	Can be either: (i) stable, (ii) semi-stable or (iii) non-stable
Classification by build (dry-film thickness)	As per EN ISO 2808:2007, method 6A: (i) minimal< 5 µm1; (ii) low: from 5 µm up to 20 µm; (iii) medium: > 20 µm and up to 60 µm; (iv) high: > 60 µm and up to 100 µm; (v) very high: > 100 µm.
Classification by hiding power	Can be either: (i) opaque (coating systems that obliterate all substrate colour and pattern but might not hide all surface profile), (ii) semi-transparent (Coating systems that do not totally obscure the wood surface) or (iii) transparent (coating systems that allow the wood surface to remain clearly visible)
Classification by gloss	As per EN ISO 2813 and based on specular reflectance values when tested at 60°: (i) matt: reflectance < 10; (ii) semi matt (satin): reflectance > 10 and up to 35; (iii) semigloss: reflectance 35 - 60; (iv) gloss: reflectance 60 - 80; or (v) high gloss: reflectance > 80.
Classification by exposure conditions	There are 3 factors to determine: (i) compass orientation (score 1 - North west to north east (moderate); score 2 - North east to south east and west north west to north west (hard); score 3 - South east to north west (extreme); (ii) degree of shelter (score 1 – sheltered; score 2 - partly sheltered; score 3- unsheltered); (iii) inclination (score 1 – Vertical; score 2- ≈ 45°; score 3 – horizontal). The exposure conditions are categorised, based on the conditions above as: a) mild (total score of 3); b) medium (total score is 4 to 6); c) severe (total score is 7 to 9).

Source: JRC own elaboration from EN 927-1.

Table 8. Different product and performance categories under EN 927-2 (performance specification).

Category	Options available
Classification by end-use (natural weathering criteria)	As per EN 927-3, according to natural weathering, a product can be (i) stable, (ii) semi-stable; or (iii) non-stable by measurements of blistering (0.3; 0.7; 1); cracking (0.7; 1.7; 3); flaking (0.3; 0.7; 1.3); adherence (1; 1; 1).
Classification by end-use (water absorption criteria)	As per EN 927-5, according to water absorption value, a product can be either: (i) stable (30 g/m$_2$ to 175 g/m$_2$), (ii) semi-stable (30 g/m$_2$ to 250 g/m$_2$) or (iii) non-stable > 30 g/m$_2$)

Source: JRC own elaboration from EN 927-2.

2.3.4 ISO 4618: Paints and varnishes: Vocabulary

A brief review of this standard showed that it was purely about terms and definitions and that the definitions were only very general. The vast majority of definitions were for individual ingredients used in paints and varnishes, but these do not constitute “technical categories” of paint and varnish products. The most relevant definitions at the level of paint and varnish products were:

- (2.19) Anti-fouling paint: coating material applied to the underwater sections of a ship´s hull or to other underwater structures to discourage biological growth.
- (2.25) Barrier coating material: coating material used to isolate a coating system from the substrate to which it is applied, in order to prevent chemical or physical interaction, e.g. to prevent bleeding or migration from an underlying coat or substrate.
- (2.47) Clear coating material: coating material which when applied to a substrate forms a solid transparent film having protective, decorative or specific technical properties.
- (2.51) Coating material: product, in liquid, paste or powder form, that, when applied to a substrate, forms a layer possessing protective, decorative and/or other specific properties.
- (2.52) Coating powder: coating material in powder form which, after fusing and possibly curing, gives a continuous film.
- (2.100) Etch primer: primer, often supplied as two reactive components mixed immediately prior to application, designed to react with a metal surface to improve the adhesion of subsequent coats.
- (2.142) Impregnating material: low viscosity coating material for the treatment of absorptive substrates to reduce their absorptivity.
- (2.148) Lasure: coating material, solvent- or water-based, containing small amounts of a suitable pigment and/or extender and used to for a transparent or semi-transparent film for decoration and/or protection of the substrate.
- (2.184) Paint: pigmented coating material which, when applied to a substrate, forms an opaque dried film having protective, decorative or specific technical purposes.
- (2.206) Primer: paint that has been formulated for use as a priming coat on prepared surfaces.
- (2.226) Multi-pack product: coating material that is supplied in two or more separate components which have to be mixed before use in the proportions specified by the manufacturer.
- (2.226) Sealer: coating material, generally unpigmented, applied to absorbent substrates prior to painting to reduce the absorptivity and/or to consolidate the substrate.
- (2.232.1) Shop primer: (generally) a protective coating material for application in the workshop to a component that is subsequently to be finished on site.
- (2.232.2) Shop primer: a surface preparation coating material that is applied to a steel substrate directly after abrasive blast-cleaning.
- (2.243) Strippable coating: a coating material removable by simple detachment from a substrate to which it is intended to provide a temporary protection.
- (2.266) Varnish: a transparent coating material.
- (2.273) Wash primer: a special form of etch primer containing balanced proportions of an inhibitive pigment, phosphoric acid and a dissolved synthetic resin, generally a poly(vinyl butyral).
- (2.274) Water-based or water-borne coating material: a coating material in which the main component of the volatile matter is water.
- (2.276) Water-soluble coating material: a coating material in which the binder is soluble in water.
- (2.277) Water-thinnable or water-dilutable or water-reducible coating material: a coating material whose viscosity is reduced by the addition of water.
- (2.281) Wood preservative: product containing a biocide which is intended to inhibit the development of wood-destroying and/or wood-staining organisms in the wood to which it is applied.

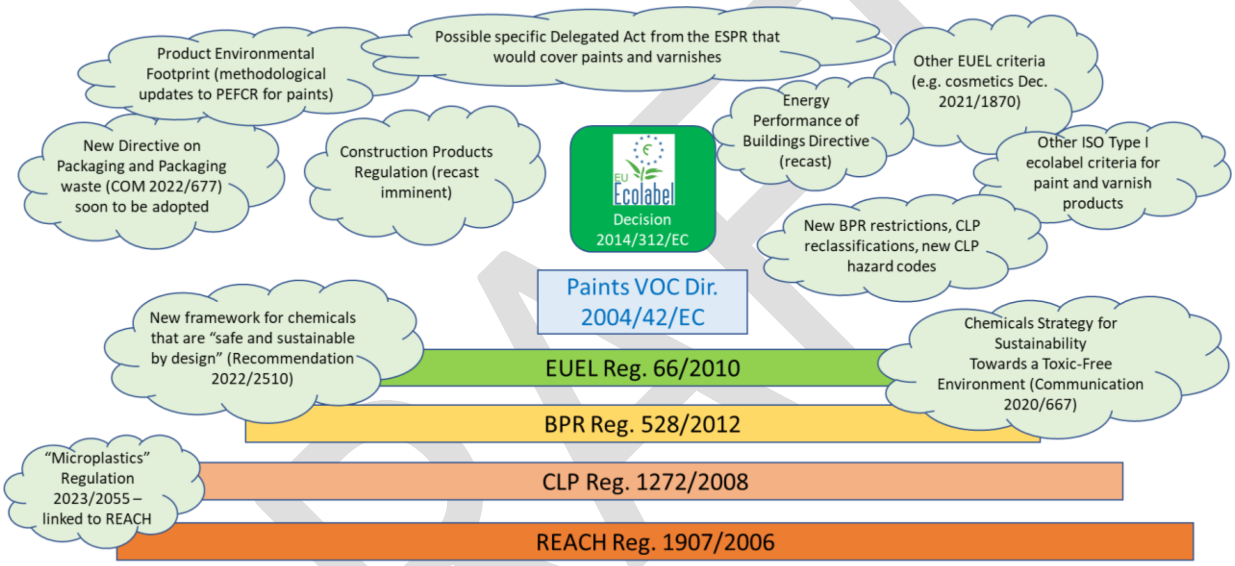
— (2.282) Wood stain: a penetrating composition containing a dyestuff that changes the colour of a wood surface, usually transparent and leaving no surface film, the solvent for which may be oil, denatured alcohol or water.

— (2.285) Zinc-rich paint / Zinc-rich primer: anti-corrosion coating material incorporating zinc dust in a concentration sufficient to give initial cathodic protection.

2.4 Relevant legislation for indoor and outdoor paints and varnishes in the EU

This section provides an overview of the regulatory frameworks that are most relevant to the paint and varnish products covered by Commission Decision 2014/312/EU. To provide the best overview, the differing degrees of relevance of each framework are highlighted, zeroing in on the most suitable parts of these often very broad frameworks. Also, the potential influence of other relevant EU policy on future EU Ecolabel criteria for paints and varnishes has been flagged.

Figure 1. Illustration of particularly relevant regulatory and EU policy context for EU Ecolabel paint and varnish products.



Source: Own elaboration.

At the centre of the illustration is Commission Decision 2014/312/EU, which constitutes the legal text for the EU Ecolabel criteria for paints and varnish products. The main regulatory frameworks are delineated by sharp boxes and in a hierarchal framework that reflects both their degree of specific relevance to the paint and varnish product group and the general breadth of the regulatory scope.

From Figure 1, the most specific regulatory framework is that of Directive 2004/42/EU on the limitation of Volatile Organic Compounds (VOCs) in different types of paint and varnish. This Directive is exclusively focused on paints and varnishes and defines product categories in a very similar way to the EU Ecolabel criteria.

Another directly relevant regulatory framework is Regulation (EC) No 66/2010 on the EU Ecolabel. While the connection to EU Ecolabel paints and varnishes is obvious, it is worth noting that the EU Ecolabel applies to 24 other product groups and services listed on the DG ENV website, such as furniture, tissue paper, cosmetic products, textiles and tourist and accommodation services – just to name a few. The EU Ecolabel Regulation stipulates certain horizontal requirements on hazardous substance restrictions and this, in turn, makes relevant the regulatory frameworks set out in:

— Regulation (EU) No 528/2012 on biocidal products (for many different uses);

— Regulation (EC) No 1272/2008 on Classification, Labelling and Packaging (CLP) of substances and mixtures (for a great variety of substances and mixtures, with or without biocidal products). This regulation was revised in 2023 and now includes new hazard classes for chemical compounds and clarification of rules on labelling[16];

— Regulation (EC) No 1907/2006 on the Registration, Evaluation, Authorisation and restriction of CHemicals (REACH) is the basis for CLP and also resulted in the creation of the European Chemicals Agency and effectively replaced a number of pre-existing regulations on hazardous substances.

Other pieces of legislation relevant for EU Ecolabel license holders are currently under revision and are expected to be published in 2024, including the Directive on Empowering Consumers for the Green Transition (ECGT), the Ecodesign for Sustainable Product Regulation (ESPR) and the Construction Products Regulation (CPR). Moreover, the Packaging and Packaging Waste Regulation (PPWR)[17] is soon-to-be adopted. Shown in Figure 1 are a number of "clouds" – these represent the less solid but potentially important influences of existing EU policies or near-future developments in such policies.

In the sub-sections of this chapter, the relevant regulatory frameworks are elaborated on in more detail, focusing on the parts of these regulations that are most suitable to consider for the purposes of revising the EU Ecolabel criteria for indoor and outdoor paints and varnishes.

2.4.1 Directive 2004/42/EC on limits for VOCs in paints and varnishes

Directive 2004/42/EC is highly relevant to the EU Ecolabel criteria for paints and varnishes as it is exclusively focused on this product group and focusing on limiting health impacts of paints. The main purpose of this legislation is to place limits on the VOC (Volatile Organic Compound) content in different categories of paint and varnish products. Criterion 4 of the EU Ecolabel also sets (more ambitious) limits on VOC content.

As mentioned at the beginning of section 2, the scope of EU Ecolabel criteria for paints and varnishes largely uses the same categories as Directive 2004/42/EC. A comparison of VOC limits is provided below.

Table 9. VOC content limits in Directive 2004/42/EC and Decision 2014/312/EU.

Category	Legal requirement Directive 2004/42/EC limit	EU Ecolabel requirement Decision 2014/312/EU limit
a) 'matt coatings for interior walls and ceilings' means coatings designed for application to indoor walls and ceilings with a degree of gloss ≤ 25@60°.	VOC: 30 g/L (water borne) VOC: 30 g/L (solvent borne)	VOC: 10g/L SVOC: 30g/L** or 40g/L***
b) 'glossy coatings for interior walls and ceilings' means coatings designed for application to indoor walls and ceilings with a degree of gloss > 25@60°.	VOC: 100 g/L (water borne) VOC: 100 g/L (solvent borne)	VOC: 40g/L SVOC: 30g/L** or 40g/L***
c) 'coatings for exterior walls of mineral substrate' means coatings designed for application to outdoor walls of masonry, brick or stucco;	VOC: 40 g/L (water borne) VOC: 430 g/L (solvent borne)	VOC: 25g/L SVOC: 40g/L
d) 'interior/exterior trim and cladding paints for wood, metal or plastic' means coatings designed for application to trim and cladding which produce an opaque film. These coatings are designed for either a wood, metal or a plastic substrate. This subcategory includes undercoats and intermediate coatings;	VOC: 130 g/L (water borne) VOC: 300 g/L (solvent borne)	VOC: 80g/L SVOC: 50g/L** or 60g/L***
e) 'interior/exterior trim varnishes and woodstains' means coatings designed for application to trim which produce a transparent or semi-transparent film for decoration and protection of wood, metal and plastics. This subcategory includes opaque woodstains. Opaque woodstains means coatings producing an opaque film for the decoration and protection of wood, against weathering, as defined in EN 927-1, within the semi-stable category;	VOC: 130 g/L (water borne) VOC: 400 g/L (solvent borne)	VOC: 65g/L (interior) SVOC: 30g/L (interior) VOC: 75g/L (exterior) SVOC: 60g/L (exterior)

16 See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008R1272-20231201

17 https://environment.ec.europa.eu/publications/proposal-packaging-and-packaging-waste_en

Category	Legal requirement Directive 2004/42/EC limit	EU Ecolabel requirement Decision 2014/312/EU limit
f) 'minimal build woodstains' means woodstains which, in accordance with EN 927-1:1996, have a mean thickness of less than 5μm when tested according to ISO 2808: 1997, method 5A;	VOC: 130 g/L (water borne) VOC: 700 g/L (solvent borne)	VOC: 50g/L SVOC: 30g/L** or 40g/L***
g) 'primers' means coatings with sealing and/or blocking properties designed for use on wood or walls and ceilings;	VOC: 30 g/L (water borne) VOC: 350 g/L (solvent borne)	VOC: 15g/L SVOC: 30g/L** or 40g/L***
h) 'binding primers' means coatings designed to stabilise loose substrate particles or impart hydrophobic properties and/or to protect wood against blue stain;	VOC: 30 g/L (water borne) VOC: 750 g/L (solvent borne)	VOC: 15g/L SVOC: 30g/L** or 40g/L***
i) 'one-pack performance coatings' means performance coatings based on film-forming material. They are designed for applications requiring a special performance, such as primer and topcoats for plastics, primer coat for ferrous substrates, primer coat for reactive metals such as zinc and aluminium, anticorrosion finishes, floor coatings, including for wood and cement floors, graffiti resistance, flame retardant, and hygiene standards in the food or drink industry or health services;	VOC: 140 g/L (water borne) VOC: 500 g/L (solvent borne)	VOC: 80g/L SVOC: 50g/L** or 60g/L***
j) 'two-pack performance coatings' means coatings with the same use as one-performance coatings, but with a second component (e.g. tertiary amines) added prior to application;	VOC: 140 g/L (water borne) VOC: 500 g/L (solvent borne)	VOC: 80g/L SVOC: 50g/L** or 60g/L***
k) 'multicoloured coatings' means coatings designed to give a two-tone or multiple-colour effect, directly from the primary application;	VOC: 100 g/L (water borne) VOC: 100 g/L (solvent borne)	Not listed (typo?)
l) 'decorative effect coatings' means coatings designed to give special aesthetic effects over specially prepared pre-painted substrates or base coats and subsequently treated with various tools during the drying period.	VOC: 200 g/L (water borne) VOC: 200 g/L (solvent borne)	VOC: 80g/L SVOC: 50g/L** or 60g/L***
'anti rust paints' (no definition)	n/a	VOC: 80 g/L SVOC: 60g/L

*g/L limits refer to content in the ready to use product

** Indoor varnishes and white paints

*** Indoor tinted paints or outdoor paints and varnishes

Source: Own elaboration based on Directive 2004/42/EC and Decision 2014/312/EU.

From the table above, it can be seen that there is almost a full overlap in scope between Directive 2004/42/EC and Decision 2014/312/EU. In terms of limits on VOC, the Directive is setting the legal upper limit for all such paint and varnish products on the EU market. By its nature, EU Ecolabel requirements are consistently more ambitious, as it is highlighting "best products" on the market. The EU Ecolabel criteria also go further in this regard in terms of setting limits on the content of SVOCs (Semi-Volatile Organic Compounds). The VOC and SVOC limits in the EU Ecolabel criteria effectively exclude solvent-borne products from the scope.

2.4.2 Directive 2004/42/EC on limits for VOCs in paints and varnishes

By its very nature, the most relevant regulatory framework for EU Ecolabel criteria for paints and varnishes is Regulation (EC) No 66/2010 on the EU Ecolabel. The criteria for EU Ecolabel paints and varnishes were created via the procedures and methods defined in this Regulation and the revision of the criteria will likewise be carried out within this same regulatory framework.

It is worth highlighting that the EU Ecolabel is an example of an EN ISO 14024 Type I ecolabel. To be considered as a Type I ecolabel, this standard requires that the ecolabels only be awarded to relevant producers or service providers following demonstration of compliance with ecological criteria, and that those criteria have been developed in a transparent manner, with broad consultation and while considering the overall life cycle impacts of relevant products and services. Compliance with such criteria must be assessed by independent third parties. In the case of the EU Ecolabel, these parties are Member State competent bodies (see Article 4 of the Regulation).

Other key parts of the Regulation that are especially pertinent are:

- Life cycle considerations: the criteria development process must account for impacts and benefits of relevant products or services when developing criteria (see Recitals 1 and 5, Article 6(3) and various parts of Annex I)
- Hazardous substance avoidance: the potential to substitute hazardous substances for safer alternatives, or to redesign products to not need hazardous substances in the first place, is clearly stated in Article 6(3b) – a more substantial interpretation of this clause could now be relevant thanks to progress made towards establishing a European framework for "*safe and sustainable by design*" chemicals and materials[18];
- Hazardous substance restrictions and derogations: Articles 6(6) and 6(7), when they state: "The EU Ecolabel may not be awarded to goods containing substances or preparations/mixtures meeting the criteria for classification as toxic, hazardous to the environment, carcinogenic, mutagenic or toxic for reproduction" set out very ambitious but quite general restrictions on a broad range of hazardous substances, creating horizontal restrictions that need to be interpreted in the context of each set of EU Ecolabel criteria for different product groups or services. The guidance produced by the EU Ecolabel Chemicals Task Force[19] is relevant for this interpretation.
- Outputs of the process: Article 7 clearly states that the criteria development or revision process should result in the production of: (i) a preliminary report; (ii) a proposal for draft criteria; (iii) a technical report to support draft criteria proposals; (iv) a final report; (v) a user manual for EU Ecolabel applicants and competent bodies and (vi) a manual for authorities awarding public contracts.
- Influence of criteria from other ecolabel schemes for paints and varnishes: Article 7(2) implies that other EN ISO 14024 Type I ecolabels can have an important influence on EU Ecolabel criteria. A brief overview of other relevant Type I ecolabels in Europe is also included in this report, in section 6.
- Influence of cross-cutting EU Ecolabel criteria: Although not explicitly stated in the EU Ecolabel Regulation, it is important for coherence of the criteria, to align the criteria wording as far as possible when the same areas of concern apply to multiple product groups (e.g. emissions of NOx from combustion processes, specific restrictions of chemicals, use of renewable energy etc.). This will help to send a clear and more consistent signal to the supply chain, to minimise confusion and minimise potential errors in translation.

2.4.3 Construction Products Regulation (CPR)

Since paints and varnishes are mainly used in buildings, it will be important to clarify whether or not these products fall within the scope of the Regulation (EU) No 305/2011[20] on construction products. This Regulation is currently under revision and the existing Regulation already requires information on the emission of formaldehyde, volatile organic compounds (VOCs) in general and any dangerous substances, dangerous particles, or greenhouse gases into the indoor environment. In addition, under the revised regulation, the EU Ecolabel and other national or regional EN ISO 14024 Type I ecolabelling schemes officially recognised may be used to demonstrate compliance with the minimum environmental sustainability requirements, subject to specific conditions.

In terms of VOCs, the influence of the CPR focuses on emissions of VOCs from a coated surface, whereas the aforementioned Directive 2004/42/EC is focused on the total content of VOCs in-can. While the two are generally related, there may be a lack of correlation between the two measurements depending on methodological details (e.g. VOC emissions are measured after 3 and 28 days, in-can VOCs are measured at the factory).

18 See: Commission Recommendation (EU) 2022/2510, available online here: https://eur-lex.europa.eu/eli/reco/2022/2510/oj

19 See: https://rural-cluster.org/wp-content/uploads/2020/10/ecolabel_chemical_task_force_2_final_recommendations.pdf

20 See: https://eur-lex.europa.eu/eli/reg/2011/305/oj

However, if paints and varnishes are indeed covered by the CPR in the end, it will be crucial to be mindful of and examine the new CPR, which has reached political agreement and is expected to be published in 2024. It is foreseen that the new Regulation will place requirements on product information for consumers, probably via digital passports and that could also influence any consumer information requirements that are in criterion 6 of Decision 2014/312/EU.

2.4.4 Recommendation (EU) 2021/2279 on Environmental Footprint methods

Life Cycle Assessment (LCA) plays a fundamental role in the development of EU Ecolabel criteria, and this, coupled with the fact that Product Environmental Footprint Category Rules (PEFCR) have already been published for paints, means that Commission Recommendation (EU) 2021/2279[21] can be identified as a relevant piece of EU policy or legislation.

Recent developments and previous discussions for the most recently revised EU Ecolabel criteria (Absorbent Hygiene Products[22], for which no PEFCR exists), used PEF in the preparatory research or criteria development, by carrying out a PEF study. There are PEFCRs for decorative paints already in place but the scope only includes some of the paint categories covered by the EU Ecolabel (see below) and does not include varnishes.

Table 10. Comparison of scopes for decorative paint products in PEFCR and the EU Ecolabel.

Scope for paints in PEFCR (v1.0)	Scope for Directive 2004/42/EC
a) 'matt coatings for interior walls and ceilings'	a) 'matt coatings for interior walls and ceilings'
b) 'glossy coatings for interior walls and ceilings'	b) 'glossy coatings for interior walls and ceilings'
c) 'coatings for exterior walls of mineral substrate'	c) 'coatings for exterior walls of mineral substrate'
d) 'interior/exterior trim and cladding paints for wood, metal or plastic'	d) 'interior/exterior trim and cladding paints for wood, metal or plastic'
	e) 'interior/exterior trim varnishes and woodstains'
	f) 'minimal build woodstains'
	g) primers'
	h) 'binding primers'
	i) 'one-pack performance coatings'
	j) 'two-pack performance coatings'
	k) 'multicoloured coatings'
	l) 'decorative effect coatings'
	'anti-rust paints'

Source: Own elaboration.

The PEFCR for paints also needs to be updated in order to comply with the methodology set out in Recommendation (EU) 2021/2279 and this will affect how final results are expressed based on a single score and following the weighting and normalisation procedure for results for different impact categories. The PEFCR will also determine the scope and boundary of any LCA and any cut-off rules.

2.4.5 Regulation (EU) 528/2012 on Biocidal Products (BPR)

The Biocidal Products Regulation (EU) 528/2012[23] (hereinafter referred to as the BPR) regulates the use and placing on the market of biocidal products. Only biocidal active substances that have been approved, or that are in the process of being approved, can be used in biocidal products. The biocidal products (which contain biocidal active substances) must be authorised for use in defined product types.

Of the different product types available, the most relevant ones for paints and varnishes are:

- PT6: Preservatives for products during storage (Used for the preservation of manufactured products, other than foodstuffs, feeding stuffs, cosmetics or medicinal products or medical devices by the control of microbial deterioration to ensure their shelf life).

[21] See: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021H2279

[22] See documents on JRC website: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/415/documents

[23] See: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:167:0001:0123:en:PDF

- PT7: Film preservatives (used for the preservation of films or coatings by the control of microbial deterioration or algal growth in order to protect the initial properties of the surface of materials or objects such as paints, plastics, sealants, wall adhesives, binders, papers, art works).
- PT12: Slimicides (used for the prevention or control of slime growth on materials, equipment and structures, used in industrial processes, e.g. on wood and paper pulp, porous sand strata in oil extraction).

In the EU Ecolabel criteria for paints and varnishes, the term "preservatives" is often used and appears to be limited only to the PT6 and PT7 type of biocidal products when referring to potential restrictions of hazardous substances in criterion 5 and derogations to criterion 5 (detailed in the Appendix of Decision 2014/312/EU).

For any preservatives derogated for use in EU Ecolabel paints and varnishes and that have aquatic toxicity, they have to be tested and comply with limits for bioaccumulation potential, expressed as a bio-concentration factor (BCF) or an octanol/water partition coefficient (K_{ow}).

Regarding the octanol-water partition coefficient, this test is a useful proxy measure for how readily an ingested substance could accumulate in fatty tissues of living organisms and is required under REACH to be reported for every substance that is manufactured or imported in the EU market in quantities greater than 1 tonne per year. The test method could be based on OECD test guidelines 107, 117 or 123, and is described as Method A-8 in Regulation (EC) No 440/2008.

Work on the harmonisation of biocidal active substance classifications has also led to some relevant reclassifications under the CLP (as described in sub-section 5.6).

2.4.6 Regulation (EC) No 1272/2008[24] on the Classification, Labelling and Packaging (CLP) of substances and mixtures

This CLP regulatory framework sets harmonised criteria for the classification and labelling of the vast majority of substances and mixtures placed on the EU market or imported into the EU. For substances or mixtures that exhibit any of the hazards defined within REACH and CLP, the CLP Regulation places rules about how this information must be communicated on packaging.

The CLP Regulation affects almost all the ingoing substances and mixtures that are used in paint and varnish products, but also for all other products, hence it has an extremely broad influence, while at the same time being highly relevant to paints and varnishes.

A revision of this regulation was published in 2023, in which new hazard classes for endocrine disruptors and long-lasting chemical substances were introduced. In addition, the revised Regulation clarifies rules on labelling and for chemicals sold online, with the objective of facilitating business within the EU.

2.4.6.1 Influence on interpretation and application of the EU Ecolabel Regulation

More specifically in terms of EU Ecolabel criteria, the CLP Regulation was crucial when the EU Ecolabel Chemical Task Force needed to make a legal interpretation of the following text in Article 6(6) of the EU Ecolabel Regulation:

"*The EU Ecolabel may not be awarded to goods containing substances or preparations/mixtures meeting the criteria for classification as toxic, hazardous to the environment, carcinogenic, mutagenic or toxic for reproduction (CMR), in accordance with Regulation (EC) No 1272/2008 […]*".

Some of the main interpretations that needed to be made were: (i) what is meant by "*containing*" exactly?; (ii) what is meant by "*toxic*" exactly?; and (iii) what is meant by "*hazardous to the environment*" exactly?

To be concise, the Chemicals Task Force decided that "*containing*" meant being present in any component part or homogenous material in concentrations >0.10% by weight in goods that are articles, or being present in goods that are mixtures, in concentrations >0.010% by weight.

Regarding what is meant by "*toxic*", "*hazardous to the environment*" etc., it was necessary to define this in terms of hazard codes that are linked to classifications defined in the CLP Regulation. The Chemical Task Force concluded that these terms should apply to hazard codes defined by group, and that the main difference

[24] See: https://eur-lex.europa.eu/eli/reg/2008/1272/oj

between the groups is that as the group number increases, the degree of hazard is considered less severe, and it becomes easier to request a derogation. The groups of hazard codes are as follows:

- Group 1 hazards: Category 1A or 1B carcinogenic, mutagenic and/or toxic for reproduction (CMR): H340, H350, H350i, H360, H360F, H360D, H360FD, H360Fd, H360Df.
- Group 2 hazards: Category 2 CMR: H341, H351, H361, H361f, H361d, H361fd, H362; Category 1 aquatic toxicity: H400, H410; Category 1 and 2 acute toxicity: H300, H310, H330; Category 1 aspiration toxicity: H304; Category 1 specific target organ toxicity (STOT): H370, H372; Category 1 sensitiser: H317, H334.
- Group 3 hazards: Category 2, 3 and 4 aquatic toxicity: H411, H412, H413; Category 3 acute toxicity: H301, H311, H331; Category 2 STOT: H371, H373.

It is interesting to note that it was necessary to not include ALL hazards related to toxicity (e.g. Category 4 H312, H332) or target organ toxicity (e.g. Category 3 H335, H336) or hazardous to the environment (i.e. H413) because including these less severe categories this would have made it practically impossible to make many different types of EU Ecolabel product.

2.4.6.2 Ongoing impact of CLP reclassifications

By setting cross-cutting hazardous substance restrictions based on defined CLP hazards and not on specific substances or substance groups, the EU Ecolabel has the merit of applying a scientifically consistent and rigorous approach. However, this approach comes at the cost of needing to adapt to the ever-changing classification landscape.

What is meant by a changing classification landscape is that the given CLP classification of any particular substance or mixture can change due to: (i) new rules for hazard codes in general; (ii) changes in the CLP classification rules for individual substances or mixtures, or (iii) new toxicological evidence justifying a reclassification of the substance. Any new harmonised reclassifications are published in Adaptations to Technical Progress (ATPs).

Just as an example for one restricted hazard (H317), the impact that the reclassification of isothiazoline substances (a commonly used Product Type 6 preservative that can be used in paints and varnishes) has had on how much was allowed in EU Ecolabel products been as follows:

- In the 11th ATP in 2018, MBIT[25] went from being allowed up to 100ppm in EU Ecolabel paints and varnishes to only being allowed in mixtures up to 15ppm before the whole mixture is classified as sensitising (and thus not being suitable for the EU Ecolabel).
- In the 13th ATP in 2018, MIT (Methylisothiazolinone) went from being allowed up to 200ppm in EU Ecolabel paints and varnishes to only being allowed up to 15ppm before the whole mixture is classified as sensitising (and thus not being suitable for the EU Ecolabel).
- In the 15th ATP in 2020, OIT[26] went from being allowed up to 500ppm in EU Ecolabel paints and varnishes to only being allowed up to 15ppm, and DCOIT[27] went from being allowed up to 250ppm to 15ppm, before the whole mixture is classified as sensitising.

While isothiazolines are a useful example to cite, there may be other substances of relevance in the paints and varnishes product group that have been reclassified to the extent that it significantly affects the feasibility of them being used in EU Ecolabel products.

[25] MBIT (2-Methyl-1,2-benzisothiazol-3(2H)-one)

[26] Octylisothiazolinone (OIT), 2-n-Octyl-4-Isothiazolin-3-one

[27] Dichlorooctylisothiazolinone,

2.4.6.3 Revision to the CLP Regulation

In a new development that will affect EU Ecolabel criteria for all product groups, new hazard codes for certain hazards such as ED HH, PBT, vPvB, PMT[28] will need to be taken into account. There is already a precedent for this in the recently adopted EU Ecolabel criteria for Absorbent Hygiene Products and it is presumed that the same approach would apply to these new EUH hazards for paint and varnish products.

2.4.7 Regulation (EC) No 1907/2006

The so-called REACH Regulation[29] sets the underlying regulatory framework for the CLP and BPR Regulations, including the creation of the European Chemicals Agency (ECHA) in the first place. It sets the procedures and systems for the Registration, Evaluation, Authorisation and restriction of CHemicals (REACH) on the EU market.

Figure 2. Overview of REACH Authorisation (top half) and Restriction (bottom half) processes.

Source: ECHA website for the Authorisation process and for the Restriction process.

The processes indicated above give an idea of the formality and complexity of the steps necessary and workload involved in dealing with substances of particular concern to human health or the wider environment. Of particular relevance to the EU Ecolabel are:

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[28] See ECHA website here: https://echa.europa.eu/new-hazard-classes-2023. ED HH stands for "Endocrine Disruption for Human Health", PBT stands for "Persistent, Bioaccumulative, Toxic", vPvB stands for "very Persistent, very Bioaccumulative", PMT stands for "Persistent, Mobile, Toxic".

[29] See: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:136:0003:0280:en:PDF

- the parts of REACH that refer to the completion and sharing of information in Safety Data Sheets (because these are commonly used for providing proof of compliance with certain criteria);
- the parts (Article 57 to 59) that refer to the definition and procedures for "substances of very high concern" (because these are especially restricted in EU Ecolabel criteria).

Foresight on chemicals that are going to be subjected to restrictions and conditional authorisations can also help determine the usefulness (or not) of derogation requests for certain hazardous substances in EU Ecolabel products.

Regarding nanomaterials, more details can be found in Commission Regulations (EU) 2018/1881[30] and 2020/878[31], as well as Commission Recommendation 2022/C229/01[32]. A proposal is also underway to ban the use of microplastics (synthetic polymer microparticles) in a number of different product groups via REACH[33], although paints and varnishes are not specifically targeted, except perhaps paints for road markings.

Attention must be paid to the ongoing process of the proposed revision of the REACH Regulation[34]. Some of the main aspects that will be considered in the revision process are:

- Revision of registration requirements,
- Inclusion of a Mixtures Assessment Factor (MAF),
- Simplifying communication in the supply chains,
- Revision of provisions for dossier and substance evaluation,
- Reforming the authorisation and restriction processes,
- Revision of provisions for control and enforcement.

Depending on the nature of the changes, it could have an impact on the entire EU Ecolabel Regulation (especially the interpretation and application of Articles 6(6) and 6(7)), not just the criteria for paints and varnishes.

2.4.8 Ecodesign for Sustainable Products Regulation (ESPR)

The success of Directive 2009/125/EC[35] for setting up a framework to define mandatory ecodesign requirements for energy-related products has inspired the Commission to look into setting up a similar framework that could apply to other products as well (i.e. non-energy related products). An extensive 650+ page impact assessment was published in 4 parts in Commission Staff Working Document SWD(2022)82[36] together with a 123 page proposal in Commission Communication COM(2022)142[37]. Political agreement in favour of this framework has been reached and a publication is expected in 2024.

Such a regulation could allow sector-specific and product group-specific measures to be proposed, debated and adopted, which set mandatory minimum requirements to improve the sustainability of these non-energy related product groups. Any mandatory minimum requirements under the ESPR should, in principle, be compatible and complementary to any more ambitious, voluntary requirements of any EU Ecolabel criteria for the same product group. As with the existing Ecodesign regulations for energy-related products (e.g. dishwashers, refrigerators etc.), there is a need for market surveillance to ensure that products comply with any mandatory requirements.

According to a preliminary report published by the JRC[38], paints are one of the end-use products that have been shortlisted for consideration in the ESPR, scoring 8th out of 12 shortlisted end-use products.

30 See: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32018R1881

31 See: https://eur-lex.europa.eu/eli/reg/2020/878/oj

32 See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022H0614%2801%29

33 See Commission webpage: https://ec.europa.eu/transparency/comitology-register/screen/documents/083921/1/consult?lang=en

34 See: https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-reach-revision

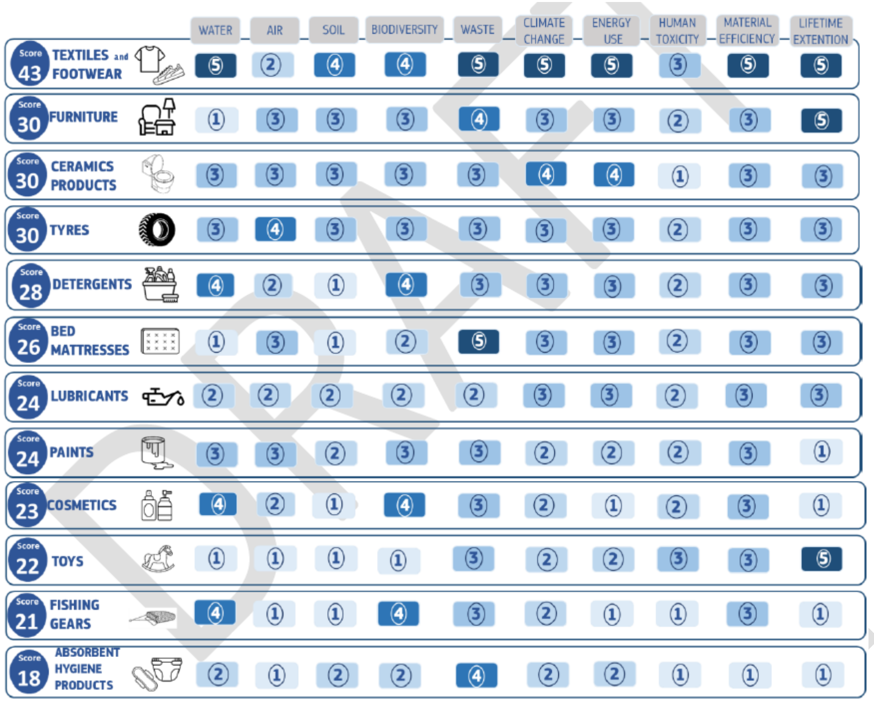
35 See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0125

36 See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022%3A82%3AFIN

37 See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A0142%3AFIN

38 See the JRC website here: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/635/documents

Figure 3. Preliminary screening of end use products for prioritisation of any ESPR working plan.



Source: https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/635/documents

The revision of EU Ecolabel criteria for paints and varnishes could potentially create a number of synergies if research is conducted with one eye on potential future ESPR criteria (e.g. on consumer information).

2.5 Review of relevant ISO Type I ecolabelling schemes and other "green" initiatives

This section addresses scope and products categorization across main ecolabel schemes and other environmental initiatives addressing paint and varnish products. The International Organization for Standardisation (ISO) has identified three types of voluntary labels:

- Type I: voluntary, multiple-criteria-based, third-party programme that awards a licence that authorises the use of environmental labels on products indicating overall environmental preference for a product within a particular product category based on life-cycle considerations. EUEL criteria fall under this category. ISO 14024 lists the guiding principles for Type I Ecolabels.
- Type II: self-declared environmental claim, i.e. environmental claim that is made, without independent third-party certification, by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such a claim, in line with ISO 14021.
- Type III: voluntary programmes that provide the quantified environmental data of a product, under pre-set categories of parameters set by a qualified third party and based on life-cycle assessment, and verified by that or another qualified third party in line with ISO 14025

On the European market, the Nordic Swan Ecolabel and Blue Angel are also ISO 14024 Type I ecolabels and are taken as a key point of reference due to the broad correspondence with EU Ecolabel.

Although these other schemes are voluntary in nature, they can have a strong influence on the EU Ecolabel criteria revision process, especially the ecolabel schemes based in Europe. Therefore, cross-checking the ecological criteria of other schemes with those of the EU Ecolabel is always a useful exercise when considering the practicalities of assessment and verification (see table below on scopes for other ISO 14024 Type I Ecolabels related to paint and varnish products).

Table 11. Comparison of scopes for other EU Type I ecolabel criteria for paints and varnishes.

Ecolabel	Scope	Included	Excluded
Blue Angel DE-UZ 12A[39]	Paints and varnishes and comparable coating substances with paint/varnishing properties for interior and exterior use as architectural paints and as industrial coatings	• Primers that are not designed for mineral subsurfaces and which do not fall under the scope of DE-UZ 102 “Low-Emission Interior Wall Paints” and are not intended for corresponding products according to DE-UZ 113 “Low-Emission Floor-Covering Adhesives and Other Covering Materials”. • Undercoats, • Clear and coloured paints and varnishes • Thin and high-build glazes, • Water-thinnable paints and varnishes,	• Wood preservatives and chemical wood preservatives with biocidal properties • Pickling solutions, • Surfacers (see DE-UZ 113 for specifications), • Waxes, • Wall paints (see DE-UZ 102 for specifications), • Printing inks, • Other coating materials without paint properties
Blue Angel DE-UZ 102[40]	Valid for wall paints according to DIN EN 13300, Point 3	• Emulsion paints according to Verband der deutschen Lackund Druckfarbenindustrie e.V. (Association of the German Coatings and Printing Ink Industry, VdL) Guideline 11, also in powder form • Primers for wall paints according to DIN EN 13300 • Silicate emulsion paints according to DIN 18363 • Paint mixing systems (base paint and pigment pastes) that are intended for use as interior wall and ceiling paint and meet the requirements for class 1-3 wet scrub resistance according to DIN EN 13300 and produce a coating thickness of <400µm according to DIN EN 1062-1	• Wall paints in the sense of these Basic Award Criteria that require labelling according to the German Ordinance on Hazardous Substances (GefStoffV) • Wall paints in the sense of these Basic Award Criteria that contain biocides, i.e. architectural paints according to VdL Guideline 01 that are intended for use outside (façade paints) • Varnishes • Primers for non-mineral subsurfaces • Emulsion varnishes • Other coating materials with paint properties • Pickling solutions • Fillers • Waxes • Printing inks • Wall paints that provide a function, such as thermal insulating paints, anti-graffiti paints, anti-mould paints, formaldehyde scavenger paints, etc. • Pigment pastes
Austrian Ecolabel UZ 01 (only in German)[41]	Varnishes, stains, and wood sealant varnishes. The primary objective of the directive is to reduce the VOC content to a maximum of 8%, or 5%	• Varnishes, stains, or sealing varnishes, among others, for wood or metal for the do-it-yourself sector or similar DIY-type varnishes, which are also sold for commercial applications	• Coating materials with biocidal treatment beyond pot preservation (film or object preservation), especially containing active

39 See: Blue Angel DE-UZ 12A

40 See: Blue Angel DE-UZ 102

41 See: Austrian Ecolabel UZ 01

Ecolabel	Scope	Included	Excluded
	for colourless varnishes. SVOCs are limited to 1%. The use of biocidal agents is strictly regulated to minimize the risk of allergies. Active substances for pot preservation are restricted. In general, ingredients that pose health risks or have environmental hazard potential are largely excluded from use.		substances against wood-damaging organisms. • Impregnations with biocidal or fire-retardant agents; inorganic-based flame-retardant additives are permissible. • Two-component systems. • Coating materials for corrosion protection [ÖNORM EN ISO 12944-5: 2018, part 5]. • Surface treatment agents containing more than 10% waxes. • Putty compounds. Wall paints are covered by Directive UZ 17.
Austrian Ecolabel UZ 17[42]	Low-emission indoor wall paints	• Silicate paints must not contain organic ingredients; • Dispersion silicate paints may include not more than 5 % of organic components • Distemper must not contain more than 2 % of organic components other than cellulose	• Coating materials whose biocide equipment goes beyond in-can conservation (film or object conservation). • Fillers and renders (with a thickness of > 400 µm or more). • Wall paints which are advertised with specific functions, like "energy-saving paints", "anti-mould paints
Nordic Swan Ecolabel criteria for chemical building products[43]	Chemical building products refers to liquid or non-hardened products for use in building work both indoors and outdoors, and on different substrates. Until further notice, the product group covers the following products for manual and machine application	• Adhesives, including multipurpose adhesive/construction adhesive • Sealants • Fillers/screed (including primers to these) • Outdoor paints and varnishes (manually applied, and including primers to these) • Paints and varnishes only for industrial application • Impregnating agents for tiles, stone, and concrete • Anti-corrosion paint for industry and infrastructure	• Solid building products such as insulation materials and plastic products, pure concrete, etc. cannot be Nordic Swan Ecolabelled under these criteria
Nordic Swan Ecolabel criteria for paints and varnishes[44]	The product group of paints and varnishes shall comprise of indoor and outdoor paints and varnishes	• Paints and varnishes, woodstains and related products, which, for decorative, functional, and protective purposes, are applied to buildings, their decorations and fixed furnishings as well as associated structures and are intended for use by consumers and professionals. The product should	• Anti-fouling coatings • Preservation products for wood impregnation (PT-8 of BPR, Regulation (EU) 528/2012) • Paints primarily intended for vehicles

42 See: Austrian Ecolabel UZ 17

43 See: Nordic Swan Ecolabel criteria for chemical building products

44 See: Nordic Swan Ecolabel criteria for indoor paints and varnishes

Ecolabel	Scope	Included	Excluded
		belong to one of the subcategories (see table 1) found in Annex I of Directive 2004/42/EC. • Paints and varnishes that have been tinted by the distributor at the request of consumers or professional decorators and tinting systems, decorative paints and varnishes in liquid, paste or powder formulas which may have been pre-conditioned or prepared by the manufacturer to meet consumer's needs • Industrial paints and varnishes used and manufactured for industrial applications, for example painting furniture/panels for indoor and outdoor use. • Anti-corrosion paint for industry and infrastructure. • Wood oils (film forming and non-film forming)	• Fillers as defined by EN ISO 4618 • Road-marking paints
Umwelt-Etikette Ecolabel UE I[45]	These UE I regulations apply to interior wall paints that are intended for use indoors. Products that are suitable for both indoor and outdoor use are manufactured in accordance with these regulations of UE I are classified and marked.	• Definitions of terms in DIN 55945 and EN ISO 4618: • Emulsion paints • Silicate paints • Dispersion silicate paints • Sol-silicate paints • Silicone resin paints • Distemper • Lime coloured • Casein colours • Natural resin colours • Clay coloured • Solvent-based matt paints • Water-thinnable matt paints • Insulating paints • Anti-mold paints • Primers • Glazes for mineral substrates • Other wall colours	• Coatings that are explicitly and exclusively for intended for outdoor use can be reported to the UE IV for facade paints.
Umwelt-Etikette Ecolabel UE II paints, wood and floor coatings inside[46]	Varnishes, wood and floor coatings intended for indoor use applied on site. Coating materials are divided into product groups based on where they are used. This corresponds to the current state of technology.	• Single component systems • Primers • Fillers • Undercoats • Impregnations / hydrophobing agents • Finishes (pigmented) • Clear coatings • Floor sealants (thin layer) • Floor coatings (thick layer)	• Coatings applied to construction units during industrial processes and delivered to construction sites as pre-coated components do not fall into the UE II scope • Coatings that are explicitly and exclusively intended for outdoor use should be registered and classified in scope UE V, intended for varnishes, wood and floor

45 See: Umwelt-Etikette Ecolabel UE I

46 See: Umwelt-Etikette Ecolabel UE II paints, wood and floor coatings inside

Ecolabel	Scope	Included	Excluded
		• Wood sealants • Parquet coatings • Wood varnishes • Wood stains • Wood waxes • Wood oils • UV-curing systems • Fire resistant coatings • Other single component systems • Multi-component systems • 2-component coatings • 2-component primers • 2-component fillers • 2-component floor sealants (thin layer) • 2-component floor coatings (thick layer) • Other multi-component systems	coatings for outdoor use and wood preservatives.

China Environmental Labelling Certification[47]	Green building materials product classification certification is in accordance with T/CECS 10039-2019 "Green Building Materials Evaluation Wall Coating"
	According to the requirements of "Materials", the certification results are divided into one-star, two-star and three-star from low to high
	Wall coating products are divided into the following 8 certification units according to product categories, processes and uses:
		Water based wall coating, performance standard:
		(GB/T 9755, GB/T 9756, GB/T 9779, HG/T 4104, HG/T 4343, JC/T 2079, JC/T 24, JC/T 157, JC/T, 172, JC/T 298 and other applicable standards)
		• Flat coating
		  ○ Water-based flat coating (for exterior walls)
		  ○ Water-based flat coating (for interior walls)
		• texture paint
		  ○ Water-based texture paint (for exterior walls)
		  ○ Water-based texture paint (for interior walls)
		• Putty paint (white cement-based powder)
		  ○ Water-based putty (for exterior walls)
		  ○ Water-based putty (for interior walls)
		Inorganic dry powder coating materials, performance standard:
		(JC/T 2083, JC/T 445)
		• Inorganic dry powder coating materials (for exterior walls)
		• Inorganic dry powder coating materials (for interior walls)
			• Not specified

Source: Own elaboration using information from Eco-labels.

Various green initiatives closely associated with ecolabels for paints and varnishes are referred to in certifications for Green Buildings. The three widely recognized global building certifications are LEED (United States), BREEAM (United Kingdom), and DGNB (Germany). These certifications encompass categories related to

[47] See: China Environmental Labelling Certification

indoor air quality, specifying points to be given according to, for example, VOC emissions for paints and varnishes used indoors. These levels are set based on other existing regulations and green schemes. For example, compliance with the Directive 2004/42/EC, described in section 5.1 of this report, is a common aspect across these certifications, used to determine a certain level of VOC, and Ecolabels is another level, giving rise to a higher number of points.

Additionally, self-declared labels falling under ISO Type II can contribute to earning points for indoor air quality in building certifications. An example is the GreenSure label by paint producer Sherwin Williams. This label is applied to a line of Sherwin Williams paints and coating products, signifying that they were developed and manufactured with measures to minimize environmental impact and meet or surpass stringent regulatory requirements. These Sherwin Williams products align with the criteria of major building certifications and standards/regulations prevalent in the US and international market, such as LEED requirements, Green Globes for New Construction, California Department of Health Services, and U.S. National Green Building Standard. Requirements for products include VOC limits, aromatic content limits, chemical component restrictions (i.e. excluded ingredients such as benzene, formaldehyde); standards for stain removal, opacity, and abrasion resistance; lead, formaldehyde, chromate hazard free; water reducible and HAPs free.

The integration of Ecolabels and Green Building Certifications provides a robust framework for advancing sustainability in the paint and varnishes sector, but care should be taken to maximise synergies between requirements for ecolabels and those of Green Building Certification schemes.

2.6 Other background information

This section presents information which was collected before the start of the revision process. First, it summarises the most important considerations from the discussion on the scope definition in the previous revision. Secondly, it presents the results from a preliminary scope questionnaire, which was sent to stakeholders in June 2023 to analyse the potential interest to expand the existing scope to other indoor and outdoor paints and varnishes products.

2.6.1 Input from last revision process

During the final stages of the last revision process, some points were raised to be further investigated. These points can be summarised as follows:

- reassess the feasibility of setting criteria for managing unused paint and re- using/recycling paint;
- reassess the feasibility of setting criteria for indoor air quality requirements based on emission tests;
- investigate setting criteria for binders;
- investigate setting criteria for nanomaterials;
- investigate setting criteria for paint packaging and recycled content;
- reassess the use of MIT as a preservative and evaluate new scientific evidence and EU legislation.

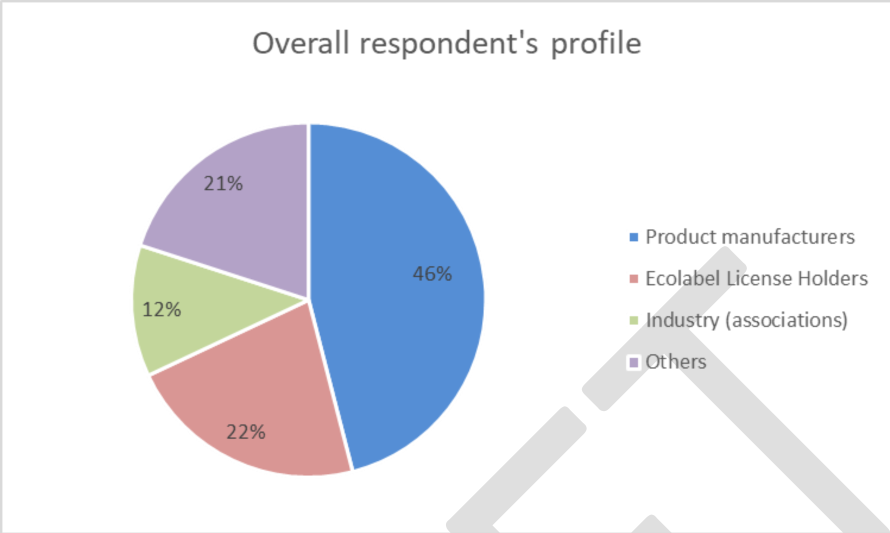
2.6.2 Stakeholder preliminary questionnaire

Prior to the start of the revision process, a questionnaire (hereinafter, preliminary questionnaire) was sent to relevant stakeholders in order to collect feedback on the validity of the current EUEL criteria for paints and varnish products and to identify priority areas to be taken as a starting point for the revision process.

The preliminary questionnaire survey period ran for eleven weeks (21/06/2023 – 06/09/2023) and its target audience included EU Ecolabel Competent Bodies, current license holders, industry, technology institutes and trade associations. A total of 73 respondents answered the preliminary questionnaire.

Regarding the respondent profile, the majority of respondents (46%, 42 answers) correspond to industry (product manufacturers) while around a quarter (22%, 20 answers) of the total, correspond to Ecolabel License Holders. Other relevant stakeholders (12%, 11 answers) are industry associations, and the remaining 21% (19 answers) were any other type of stakeholder. Considering the total number of received responses (73 answers) for scope approval, it is assumed that stakeholders could answer more than one profile, resulting in an overlap in respondent profiles. For instance, a stakeholder who is a product manufacturer might also be a license holder.

Figure 4. Profile of respondents to the questionnaire



Source: European Commission, Joint Research Centre, 2023[48].

2.6.3 Feedback from stakeholder consultation on the scope and definition

Most respondents agreed with current scope, over 46% (34 answers) replied that the scope and definition are adequate and valid for the product group. However, nearly one quarter of the respondents (23%, 17 answers) claimed that the scope and definition need to be revised, updated and/or changed. Additionally, 22 stakeholders (30%) did not answer.

When stakeholders were asked if the current scope of EUEL criteria should be enlarged to include other products based on suggestions already received from stakeholders (i.e. to include water-based aerosol paints, road marking paints, powder/cement products, wood oils, waterproofing products), most of respondents, i.e. between 58 to 69% of answers claimed that scope does not need to be modified. However, 1 to 5% saw the need for minor changes. Some 26 to 31% of respondents did not provide an answer.

Stakeholders pointed out that:

— The existing criteria are tailored for a category of products characterized by uniform technical features and regulation, specifically those governed by Directive 2004/42/EC, commonly referred to as the 'Decopaint' Directive for decorative and film-forming products. The other suggested product classifications diverge from this directive and, in certain instances, adhere to distinct product directives, such as aerosols (Directive 75/324/EEC as amended). Integrating these products, especially aerosols, powder/cement products, and others, would add another layer of complexity to the existing criteria, which are already quite complex to date.

— Clear lack of substantial market interest in obtaining EU Ecolabel certification for the proposed products, rendering their incorporation into the scope of EU Ecolabel irrelevant, for now.
— It should be investigated whether the proposed product(s) are relevant to be covered under the EU Ecolabel, whether it is included in other Type I ecolabels, and whether the specifics of that product require settings criteria or thresholds that are very different from the products already in the scope.

Stakeholders were also asked whether harmonization with any specific criteria of other ISO Type I ecolabels should be considered, and if yes, which. The responses were as follows:

48 European Commission, Joint Research Centre;; 2023. Revision of the EU Ecolabel Criteria for Indoor and Outdoor Paint and Varnish Product Group: Summarised outcomes of the preliminary questionnaire on the current criteria (internal document).

- In regard of the Article 11.2 of the Regulation 66/2010, it is conceivable to harmonize with other ISO Type I labels. The criteria from these labels should be pertinent to all countries participating in the EU Ecolabel and should streamline the process of criteria revision.
- It was proposed to consider the French IAQ regulation[49]. This regulation assesses the emissions of indoor paints and varnishes 28 days after application, classifying them based on their emissions.
- Harmonizing criteria across ecolabels is a sensible approach to prevent competition and enhance the ambition of ecolabel criteria over time. However, since criteria for paints among different ecolabels are not uniformly aligned, the EU Ecolabel must decide which standard or elements to align with. The preference is generally for alignment with the criteria of other Type I ecolabels that are both recent and ambitious.

The stakeholders' inputs were carefully analysed and taken into account. The conclusion is to refrain from expanding the criteria's scope to include additional products, but to ensure a clearer product scope and concise criteria during the revision. The various perspectives and insights provided by stakeholders have been carefully weighed, leading to the conclusion that the existing scope adequately addresses the criteria without the need for further expansion.

A question to Competent Bodies (CBs) was if they had been contacted by producers or others who have had difficulty in understanding the scope and/or the criteria. To this question, 14 answers were received. While 9 answers said that no difficulties were raised, 6 answers highlighted:

- Some difficulties to understand which products fall under the scope.
- The limitations for license-holders to update the license.
- Some unclear or vague criteria.
- Requests reaching CBs not only from manufacturer/applicants but also from suppliers of raw materials in order to better understand the decision.
- Another comment claimed that the criteria are not easy to follow and suggested the structure could be modified and language simplified.
- Given the high number of derogations, the need to have long discussions with applicants.

2.7 Methodology to assess the potential of inclusion

The selection of which product categories should be included in the scope has been done considering the following relevant aspects:

- Inclusion in other Ecolabels and environmental schemes (according to data provided in Section 2.5).

2	At least 1 EU-based scheme includes the product group.
1	No EU-based scheme includes the product group, but at least 1 non-EU scheme does.
0	No schemes include the product group.

- Stakeholder's interest in the inclusion of specific product (according to data provided in Section 2.6).

2	Support from multiple stakeholders from different interest groups for inclusion.
1	Very little or no support for inclusion except for stakeholders formally requesting inclusion.
0	No stakeholders have formally requested the product categories to be included.

- Market share of the product (according to data provided in Section 2.6.2 and section 3).

2	More than 1 million units sold per year and/or more than 10 million EUR per year in sales value in the EU27
1	Between 200,000 to 1 million units sold per year and 1-10 million EUR per year in sales value in the EU27
0	Less than 200,000 units sold per year and/or less than 1 million EUR per year in sales value in the EU27

[49] Décret n° 2011-321 du 23 mars 2011 relatif à l'étiquetage des produits de construction ou de revêtement de mur ou de sol et des peintures et vernis sur leurs émissions de polluants volatils

— Environmental impacts (according to data provided in Sections 4.2 to 4.4).

2	High similarity
1	Medium similarity
0	Low similarity

— Similarity of formulation components, compared to products included in the existing scope (according to data provided in Section 4.1).

2	High similarity
1	Medium similarity
0	Low similarity

The results of this evaluation are presented in Table 12 where the potential for inclusion of the products have been done considering the following scale. Once the classification is completed, a total punctuation from 0 to 10 could be obtained.

Punctuation	0	1	2	3	4	5	6	7	8	9	10
Potential for inclusion	Low				Medium			High			

Table 12. Summary of the product group categories and assessment of the potentially inclusion in the scope

PRODUCT CATEGORY	Inclusion in other Ecolabels and environmental schemes	Interest of stakeholders	Market relevance (EU 27)	Environmental impacts	Formulation similarity with products currently in the scope	Potential for inclusion
water-based aerosol paints	0	1	1	2	0	Medium
road marking paints	0	0	0	1	1	Low
powder/cement products	2	0	Unknown	2	0	Medium
wood oils	2	2	Unknown	?	0	Medium
waterproofing products	0	1	Unknown	2	1	Medium

Source: Own elaboration.

Regarding the above assessment of the relevance of products proposed as part of a potential scope expansion, most of the products achieved a medium score, despite a current lack of knowledge about the market relevance of the additional product groups.

Aerosol spray paints have a higher environmental relevance when it is considered that a potential EU Ecolabel would represent a complete shift from organic solvent-based formulations to water-based formulations. The environment impact reduction potential for cement paints is high as well, since there are many ways to reduce the impact of cement, for example by producing the cement from energy efficient kilns, by using alternative fuels in the kilns, by increasing the use of supplementary cementitious materials and so on. Aggregates used in cement paints could also be potentially sourced from secondary or recycled materials.

In terms of other relevant ecolabel schemes, waterproofing products have criteria in Blue Angel while both the wood oils and the cement paint have criteria in Nordic Swan and Blue Angel criteria. Although a closer examination of what the full requirements are would be needed if stakeholders confirm that they want these products to be included it in the scope.

2.8 Concluding remarks on the preliminary scope analysis

This chapter addresses the key findings from the preliminary scope analysis. Suggested changes to the criteria scope and definitions have been collated following the review of the policy background, stakeholder feedback, Type I ecolabels, and other voluntary agreements.

Overall, from the information provided in this report, it is clear that there are many different potential technical categories of paint and varnish products, and that these do not complement each other very well. In addition to this complexity, it must also be added that none of these technical categories correspond clearly to the PRODCOM statistical categories described in section 3, Market Analysis.

During and after the November 2023 EUEB meeting, EUEB members were asked about potential updates to the scope and definitions, based on suggestions to expand the scope from certain industry stakeholders.

Table 13. Summary of feedback on potential scope expansion for EUEL paints and varnishes.

Should the current SCOPE of EU Ecolabel criteria for paints and varnishes be enlarged to include other products (suggestions already received from stakeholders: water spray aerosol paints, road marking paints, powder/cement products, wood oils, waterproofing products)?	
Respondent type	Anonymised response
Member State representative	We are not in favour of expanding the scope. We would really prefer to maintain the exclusions already defined in the current criteria. Maybe it should be investigated case by case during the process of the revision of criteria.
Member State representative	These suggested product categories are indeed excluded from the current scope for EU Ecolabel paints and varnishes. The current criteria are set on a group of products that are homogeneous in terms of technical characteristics and legislation: those products regulated by Directive 2004/42/EC, known as the 'Decopaint' Directive as decorative and film-forming products. The other proposed product categories do not fall under this directive and in some cases have specific product directives, such as aerosols (Directive 75/324/EEC as amended). Including these products, in particular aerosols, powder/cement products and others, would further complicate the architecture of the criteria, which are already very complex to date. These products would probably need their own criteria.
Member State representative	Our opinion is no scope extension to include the proposed product types, unless there is apparent high market interest in EU Ecolabel certification for them. We have not noted such market interest in our Member State.
Member State representative	Even though some companies may agree on enlarging the scope, our opinion is that, to expand the scope of the category, it is necessary to take into account the regulations of the different types of products. For instance, decorative and film-forming products are regulated by Directive 2004/42/EC, but other products such as aerosols are regulated by other directives (Directive 75/324/EEC and subsequent amendments). We think that including new products (in particular aerosols, powder/cement products and others) would further complicate the structure of the criteria, which is already very complex today. In any case, if the scope is enlarged, we would appreciate that both the definition of the new scope and the new criteria are very clear and structured, which probably would require separate criteria that are not included in the Decision that regulates current decorative paints.
NGO representative	We think the current scope is adequate. In case an extension to certain further products is considered, it should be investigated whether this product is relevant to be covered under the EU Ecolabel, whether it is included in other Type I ecolabels, and whether the specifics of that product require settings criteria or thresholds that are very different from the products already in the scope.

Should the current SCOPE of EU Ecolabel criteria for paints and varnishes be enlarged to include other products (suggestions already received from stakeholders: water spray aerosol paints, road marking paints, powder/cement products, wood oils, waterproofing products)?	
Respondent type	Anonymised response
	For example, we imagine that road marking paints would require very high resistance and durability characteristics and could therefore trigger a debate around higher preservative levels, possibly also affecting other products. From what we have seen, road marking paints are not included either in other ecolabels, e.g. the Nordic Swan.
Member State representative	Regarding road marking paints: are we talking about paints that are brushed or that are sprayed onto the street? If sprayed, from our perspective they cannot be included in the scope of the EU Ecolabel. If brushed, could we have a look into the list of ingredients? Regarding powder/cement products, there are Blue Angel criteria for low emission internal plasters (DE-UZ 198). Regarding wood oil, this can be included in the scope as long as it does not form a closed surface and does not contain biocides. A distinction between interior and exterior wood oil would be very useful so the requirements could be formulated more specific. Regarding waterproofing products, we do not understand how waterproofing products could fit into paints and varnishes. Maybe you could explain these products in more detail.
Member State representative	We are not against any of the suggestions mentioned above. There has been interest towards the first and the last in our country (water spray aerosol paints and waterproofing products). Regarding aerosol products, the propellant may be in a separate "bag" inside the aerosol can/bottle so that it is not released into the atmosphere. The legibility of the criteria shall be made better and specially if the document covers several new types of products, we should pay very much attention to this.
Industry representative	Our organisation does not support the expansion of the product group scope.
Nordic Member State representative	Nordic Ecolabelling has been asked specifically about including aerosol paints and road marking paints in the scope of the Nordic Swan Ecolabel (NSE) criteria. However, there was not enough interest and time to prioritise it as the revision focused on other parts. Also, SE CB is reluctant to include consumer aerosol paints in general. Cement paints and powder paints are included in the NSE criteria. If cement paints are to be included in the EUEL criteria, we strongly suggest that relevant requirements should be set focusing on the production of cement, as it heavily contributes to the overall climate impact of the paint. You can find background to the NSE criterion in the "Background document, version 4.1" on our website. Wood oils (both film-forming and non-film-forming) are included in the NSE criteria as there has been many requests by license holders to ecolabel such products as a component of a paint product system. While non-film-forming wood oils do not fulfil the original NSE criteria definitions of a "paint" or a "varnish", we included them in the scope since we believe it was a relevant reason to complete the set-up of an ecolabelled paint system. Moreover, also when not used as part of a system, wood oils are an alternative of choice when the natural pattern and colour of wood is to be preserved. We ask for clarity regarding the mention of waterproofing products as a possible EUEL criteria extension. If it regards wet-room paints then yes, we agree. If it relates to waterproofing membranes we do not agree it fits the scope of the criteria since this product is "built in" and does not resemble a paint.
Member State representative	Until now, we have not received any expression of interest from any stakeholder for "paints and varnishes" products other than applications for indoor paints. In fact, we currently have only 6 active licenses within this product group and all of them covering indoor paints. We would like to share the feedback that some economic operators have given to us, namely that their lack of interest in EU Ecolabel is because the way the Decision is currently structured and the lack of a supporting calculation EXCEL sheet, which makes potential LH to lose interest in investing time in a possible application. For this reason, we are not sure if the extension of the scope (water spray aerosol paints, road marking paints, powder/cement products, wood oils, waterproofing products) will have immediate impact if the revision of the Decision will not aim at making it more "friendly" to better support applications.

Should the current SCOPE of EU Ecolabel criteria for paints and varnishes be enlarged to include other products (suggestions already received from stakeholders: water spray aerosol paints, road marking paints, powder/cement products, wood oils, waterproofing products)?	
Respondent type	Anonymised response
	Within a possible future revision of this Decision, we would suggest focusing on an improved structure of the text, namely different annexes regarding different product typologies (e.g., Annex I - Paints for indoor and outdoor, Annex II – Varnishes, ...).

Source: Own elaboration

The feedback received from stakeholders was predominantly negative, indicating a consensus against expanding the scope and definitions. The reasons cited include the complexity of the current criteria already being high enough, the distinct regulations governing different product types, and the potential need for very distinct criteria for new products. Stakeholders emphasized the adequacy of the current scope unless there is significant market interest. A single stakeholder wished to include water-based aerosol spray paints in the scope.

The main concern with aerosol paints and any sprayed road marking paints appeared to centre on the use of propellants, and the separate regulation by Directive 75/324/EEC and subsequent amendments. The inclusion of such diverse products in the regulatory framework would inevitably complicate the criteria's overall structure. It is noteworthy that the majority of survey respondents expressed a preference for maintaining the current scope without expansion.

3 Task 2: Market Analysis

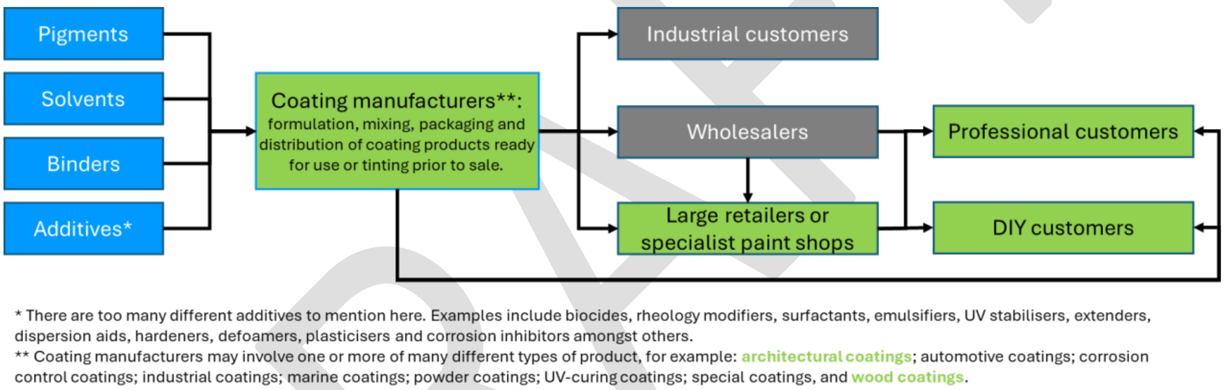
This chapter focuses on the European market for indoor and outdoor paints and varnishes and its trends at a quantitative and qualitative level for the different categories of this product group. The study outlines the market knowledge in order to support the on-going revision of the EU Ecolabel criteria for the given product group.

The task starts by describing the production value chain for these products and then presents the main actors and sales trends and forecasts at global level. A much closer look is then made into data at EU level, including a presentation of qualitative and quantitative market trends in the paints and varnish market, and in the uptake of the EU Ecolabel in the sector.

3.1 Coatings industry production value chain

The decorative paints and varnishes sector represents one part of the broader coatings industry. The vast majority of coating manufacturers depend on obtaining their ingredients from upstream suppliers, although some of the larger coatings manufacturers also produce ingredients and may sell them to other coatings manufacturers. The sale of coating products will either be exclusively business-to-business or a combination of business-to-business and business-to-consumer, depending on the nature of the product and its potential applications. A simplified illustration of the production value chain is provided below.

Figure 5. General illustration of the production value chain for coating products.



Source: Own elaboration.

The diagram above indicates how the production value chain keeps adding value as the stages go from left to right. The chain starts with raw materials of chemical and mineral feedstocks (not included above for simplicity), then proceeds to the production of ingredients for coating formulations. These ingredients are transported to sites where the desired coating formulations can be mixed and packaged prior to shipment to customers.

The direct sale from coating manufacturers to individual customers is considered to be rare in cases of sales direct to DIY and professional customers, but more common with industrial customers. The most common sales relationships that manufacturers have is to the following 3 actors:

— Industrial customers who will directly use the coating products in their own production lines (e.g. automotive coatings, coating of prefabricated construction products, of furniture etc.).
— Wholesalers that are more focussed on selling larger quantities of coating products at a good price instead of selling very small quantities to each customer.
— Large retailers or specialist paint shops with a focus on selling to individual customers for the DIY market, or to professionals who decide to purchase coating products this way. Especially with the specialist paint shops, it would be normal for white paints to be purchased as well as a number of tints that can be used to generate custom-made colours on demand from customers (private or professional).

The green-highlighted boxes represent areas where potential signals of awareness and demand can have a higher influence on the adoption of the EU Ecolabel, with ingredient suppliers playing a crucial role in formulating these into marketable products. The text in green in the footnote of the figure above implies those types of coating products that are (partially) covered by the EU Ecolabel scope.

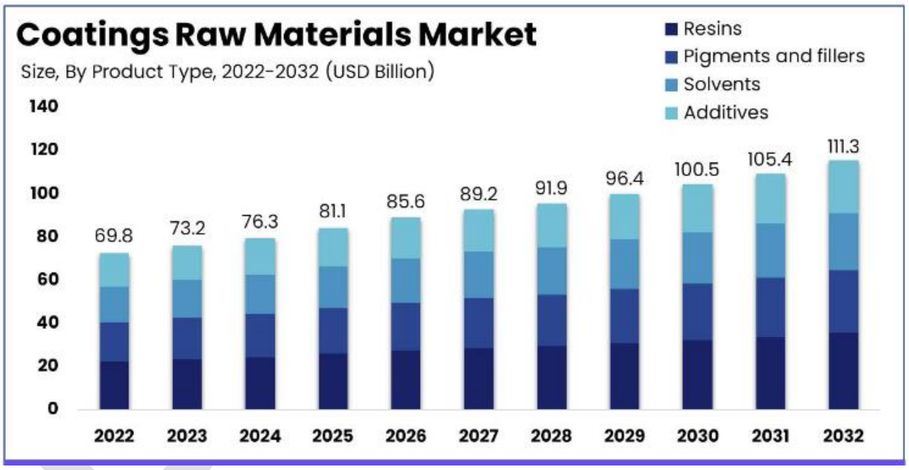
3.1.1 Raw material / ingredient suppliers

Paint and varnish products are basically mixtures composed of raw materials that are blended under controlled conditions and in precise quantities according to the know-how of manufacturers. Raw materials account for around 40-60% of paint and varnish production costs (S&P Global[51]). Solvents and polymers are very sensitive to changes in the cost of crude oil and all raw materials are sensitive to energy prices as well. Supply chain disruptions associated with COVID lockdown restrictions and risks in the Red Sea shipping route[52], have led to lasting effects on global supply chains[53,54,55], and to volatile pricing of raw materials over the last 3 years and subsequently volatile purchasing practices by coating producers.

A worldwide market research analysis report[56] estimated the raw material market for coating manufacturers to be worth around USD 111.3 billion by 2032 growing from USD 69.8 billion in 2022.

Many of the raw materials used in paints and coatings are also in demand for other sectors, such as lubricants, adhesives, cosmetics, paper, plastics, and household cleaners. An estimated breakdown of the raw materials market by volume and value in 2017 was also provided in the same ACA article.

Table 14. Coatings raw material global market estimates by value from 2022 to 2032.



Source: Coating raw material market by marketresearch.biz[56].

3.1.2 Resins

Acrylics are the most popular resin used in the global coatings market and are very popular in the decorative paints sector. They can be used in water-based and organic solvent-based systems and include both pure and

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51 See:https://www.spglobal.com/commodityinsights/en/ci/products/paint-and-coatings-industry-chemical-economics-handbook.html

52 See: Red Sea attacks: What trade experts are saying about the shipping disruptions

53 Lorenzo, M., 2023, The impact of Covid-19 on the supply chain Review of the effects of a pandemic crisis on the global supply system and analysis of its fragilities , KTH Royla Institute of Technology, Sweden.

54 EY, 2023, How COVID-19 impacted supply chains and what comes next, https://www.ey.com/en_dk/supply-chain/how-covid-19-impacted-supply-chains-and-what-comes-next

55 Fortune, 2023, How COVID changed supply chains forever, according to a distinguished professor in the field who's studied them for the last 2 decades, https://fortune.com/europe/2023/01/11/how-covid-changed-supply-chains-forever-distinguished-professor-just-in-case-just-in-time-onshoring-technology/

56 See: Coatings Raw Materials Market (2023)

modified forms, such as styrene-acrylics and vinyl-acrylics. There has been some price volatility for acrylics due to upstream supply disruptions for methyl methacrylate. Alkyd resins have been declining, and one reason for this decline is the demand for lower VOC content coating formulations. Urethane resins are used in many different coating sectors, especially in the one-pack and two-pack performance coatings sector and can be used in lower VOC formulations. Epoxy resins are mainly used in industrial coatings and marine applications and are not considered very relevant to the EU Ecolabel scope, as they are outside of the scope of the label. The other resins generally refer to amino, polyester, cellulosic, silicone/polysiloxane, silicate and vinyl resins, as well as fluoropolymers, hydrocarbon resins, natural resins like rosins and shellacs, and natural oils like linseed oil and tung oil.

3.1.3 Pigments and fillers

Paints and coatings manufacturing is the single largest sector demanding pigments (ca. 51% of global market in 2021[57]). Fillers and pigment extenders are the most common sub-category here in terms of volume. These inorganic compounds (e.g. kaolin, calcium carbonate, talc, silica, dolomite, feldspar, barium sulphate etc.) are generally much cheaper than pigments and their use is normally for the purpose of economising the use of pigments without compromising on colour. The use of fillers and pigment extenders will affect factors like rheology, sedimentation, and pH of coating formulations, as well as the texture, adhesion, barrier properties and chemical resistance of films. All these factors will influence which types of filler are most suitable for which coating formulation.

Titanium dioxide (TiO_2) is the next most important sub-category in terms of volume, and accounts for around 10% of all raw materials used in coatings. It is the most common pure pigment (31% of global pigments used in coatings) and is very popular in decorative paints thanks to its excellent physical properties. Manufacturers are always looking to reduce TiO_2 content to reduce production costs, hence the popularity of pigment extenders.

In terms of colour pigments, these can be either organic or inorganic, but are mostly inorganic due to their much lower cost. They are marketed by colour, mainly being blues, reds, oranges, yellows, greens, and blacks. Other pigments generally refer to a broad range of speciality pigments, which include anti-corrosion pigments, metallic pigments, iridescent pigments, fluorescent pigments, pearlescent pigments, and carbon black, amongst others.

Some of the leading suppliers of these types of materials include Active Minerals, Baser Mining, Brenntag, Burgess Pigment Company, Evonik Corporation, Fineton Industrial Minerals Limited, Gelest Inc., Hazmatpac Inc., Heubach Colorants USA, HSH Chemie, Hydrite, Imerys, Karntner Montanindustrie, Liberty Speciality Chemicals Inc., Malvern Modified Materials, New Brook International Inc., Organic Dyes & Pigments LLC., Shaheen Grinding Mills, Southeastern Primary Minerals LLC, Vanderbilt Minerals LLC and Vitro Minerals.

3.1.4 Additives

Just by comparing the relative shares of volume and value for the four different main categories of raw material (resins, pigments & fillers, solvents and additives), it is clear that additives have the highest average unit cost. Additives are used in small quantities and are an important part of product innovation and manufacturer know-how. The term "additives" encompasses a broad range of chemicals, of which two of the most widely known are:

Rheology modifiers: the aim of these additives is to achieve the desired viscosity for the coating formulation and other properties that will ensure the optimum behaviour of the mixture during manufacturing, storage and application. Some examples include natural organics (e.g. methyl cellulose, hydroxyethyl cellulose, xanthan gum), synthetic organics (e.g. polyacrylates and polyurethanes) or inorganics (e.g. clays and silicas).

Biocides (or preservatives): biocidal products that are used to prevent microbial spoiling of coating products are usually in the form of in-can preservatives (which prevent spoiling before use) and/or in dry-film preservatives (acting after application). Dry-film preservatives are generally used in an encapsulated form to ensure slow and gradual release over the film lifetime. Some encapsulated forms of in-can preservatives have been developed to try and comply with ever more stringent classification rules on the use of isothiazolines in

[57] See: Transparent Market Research: Pigments Market

the EU (Bergek et al., 2014[58]). The use of encapsulated preservatives for dry-film preservation works in a different way, because slow release can help prolong the protection of the dry-film and thus the useful lifetime of the coating. The Polyphase and Troysan products offered by Arxada are just two examples of encapsulated biocides for dry-film preservation. However, while paint manufacturers continuously research alternative preservation methods, a 2021 study from the Dutch government does not expect less hazardous biocides developed by biocide producers[59]. The study also found, that the go-to solution for the water-borne biocide-free paints on the market, is having high pH to prevent biological growth. This method can be used for wall paints (either white or factory coloured), but is not applicable in e.g. technical or industrial coatings.

3.1.5 Business models for raw materials suppliers

A large, multinational coating manufacturer will be dealing with hundreds or thousands of raw material suppliers. Consequently, it is worth summarising the three main types of business model for raw material suppliers to the coatings industry:

- Large, multinational chemical companies that provide many types of raw materials to many types of industry, of which the coatings industry is just one (e.g. BASF, DowDuPont, Evonik, Huntsman and Lanxess).
- Multinational companies that have specialised into a narrow range of raw materials (e.g. Cathay with pigments, Alberdingk Boley with water-based resins, Worlee-Chemie with resins and Michelman with additives). These companies tend to be the main sources of innovation in their areas of expertise.
- Local or regional suppliers that can offer different levels of customer service, tailor-made solutions and that can develop in a more dynamic manner than the larger corporations.

Information from articles on the Coatings World website about the top global companies, and also the annual reports of the largest companies in these lists, shows that business activity in the last 5-10 years has shown a lot of consolidation amongst the multinational companies, as the larger more general multinationals (or the larger multinational coating manufacturers) acquire more specialist multinationals in order to broaden their portfolio and expertise to fit with their commercial strategies.

3.2 Global trends and key actors

Global key stakeholders in the market of paints and varnishes are:

- Raw material suppliers
- Distributors/traders/wholesalers/suppliers
- Regulatory bodies, including government agencies and NGO
- Commercial research & development (R&D) institutions
- Importers and exporters
- Government organizations, research organizations, and consulting firms
- Trade associations and industry bodies
- End-use industries

3.2.1 Key actors

In terms of demand for coatings by volume, an article[60] published by the American Coatings Association estimated that, in 2017, the Asia Pacific region dominated (52%), followed by Europe (18%), North America (12%), Latin America (10%) and Middle East & Africa (8%). However, by 2022, according to StatistaError! Bookmark not defined., the Asia-Pacific region saw a reduction in demand to 45%, while Europe increased to

[58] Bergek et al., 2014. Controlled release of microencapsulated 2-n-octyl-4-isothiazolin-3-one from coatings: Effect of microscopic and macroscopic pores. Colloids and Surfaces A: Physicochemical and Engineering Aspects, Volume 458, Pages 155-167, ISSN 0927-7757, https://doi.org/10.1016/j.colsurfa.2014.02.057

[59] S. Lemain and b. Mensik, 2021, In-can preservatives in the paint industry, prepared for Ministry of Infrastructure & Water Management by HASKONINGDHV NEDERLAND B.V., https://www.government.nl/binaries/government/documenten/reports/2021/11/23/in-can-preservatives-in-the-paint-industry-how-to-stimulate-alternatives-to-biocides/in-can-preservatives-paint-industry-alternatives-biocides.PDF

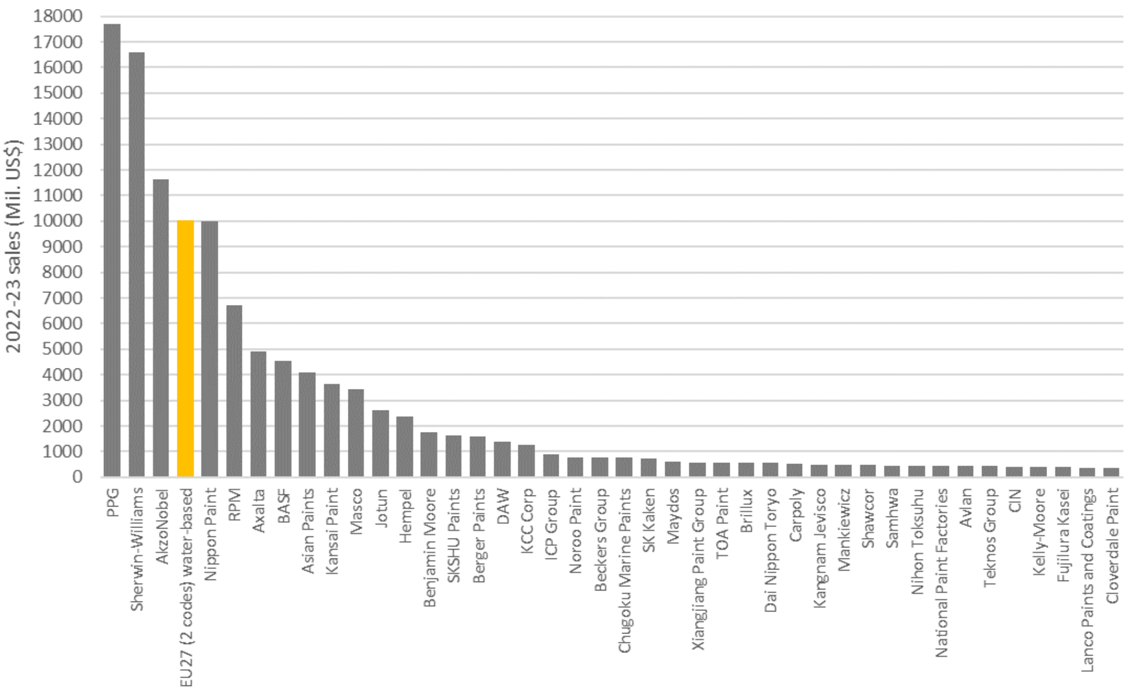
[60] See: https://www.paint.org/coatingstech-magazine/articles/demand-coatings-raw-materials-to-2022/

23%, North America to 19%, and Latin America and the Middle East & Africa decreased to 7% and 6%, respectively. Looking ahead to 2024, the World Coating Council[61] predicts the Asia-Pacific region will continue to lead with 43%, followed by Europe at 22%, North America at 19%, Latin America at 9%, and Africa at 7%.

The "Top Company Report[61]" compiled by Coatings World each year lists the largest manufacturers of paints and coatings at global level. These companies all have annual sales of $100 million or more (ca. €93 million) and are ranked in order of these numbers. According to the report, in 2023 there were 73 companies worldwide meeting this criterion - down from at least 79 in 2021 due to 6 major acquisitions within these largest manufacturers in the years 2022 and 2023.

A graphical distribution of the sales of the top global companies is shown below and compared to EU27 sales values for water-based paints and varnishes (PRODCOM codes 20301150 and 20301170).

Figure 6. Sales values for 2022-23 for the 40 biggest global paint and coating manufacturers compared to EU27 sales for water-based PRODCOM codes (assuming 0.93 EUR per 1 USD).



Source: Combination of Eurostat PRODCOM and Coatings World[62] "Top Company" data.

The sales data show two clear leading companies (PPG and Sherwin-Williams), followed at some distance by three other standout companies (AzkoNobel, Nippon Paint and RPM). After these top 5, there is a gradual decline in sales, with only a factor of 2 difference in sales between the companies in positions 20 and 40 ($760 and $380 million), and a factor of 3 difference between the companies in positions 40 and 71 ($380 and $130 million, not shown on graph).

For context, the sales values for the 2 PRODCOM codes that cover water-based paints and varnishes (20301150 and 20301170) is included for sales value of domestic production (PRODVAL). These sales would correspond to the joint 4th largest coatings producer at global level. Although it must be clarified that the top company sales will include sales from many coating products not included in the quite narrow EU27 coating product data listed. Of the biggest companies mentioned in the figure above, only some are based on the European Economic Area with the top five listed in the table below.

61 See: https://www.coatingsworld.com/issues/2023-07-01/view_top-companies-report/top-companies-report-651116/

62 See: https://www.coatingsworld.com/issues/2022-07-01/view_top-companies-report/top-companies-report-70960/

Table 15. Top 5 European paints and coatings companies (2023, based on Coatings World annual ranking report).

European ranking	Global ranking	Company	Revenue in $	Country
1	3	AkzoNobel	11.650.000.000	Amsterdam, Netherlands
2	7	BASF	4.550.000.000	Münster, Germany
3	11	Jotun	2.618.000.000	Sandefjord, Norway
4	12	Hempel	2.357.000.000	Kgs. Lyngby, Denmark
5	16	DAW	1.400.000.000	Ober-Ramstadt, Germany

Source: Coatings World news article in 2023, https://www.coatingsworld.com/issues/2023-07-01/view_top-companies-report/top-companies-report-651116/.

AkzoNobel, based in the Netherlands, is a major paint manufacturer and the largest one based in the European Economic Area with total revenue of $11650 million in 2023 (ca. €10834 million). Looking specifically at the decorative paints part of their business, their 2022 company report[63] (and previous reports) showed revenues of €2061, €2129, €2246, €2429 and €2405 million were posted by AkzoNobel in the EMEA (Europe, Middle East and Africa) region in the years 2017, 2018, 2019, 2020, 2021 and 2022 respectively. It was not possible to see data for Europe only in the report, but the EMEA region revenues for decorative paints are accounting for just over 20% of total revenues in 2022.

With Jotun, their 2022 report[64] showed that decorative paint sales were responsible for around 38% of all revenues in 2022. In the Western Europe and Scandinavia (WESCA) region, revenues increased from 6083 to 6746 million NOK between 2021 and 2022 (ca. €537 to €595 million, +10.9%). However, growth in other regions was even more significant (global revenues going from 8389 to 10246 million NOK, ca. +22%), meaning that the WESCA share of global decorative paint sales dropped from around 72.5% to 66% going from 2021 to 2022.

Of the four main business segments defined by Hempel for their operations (Marine coatings, Decorative coatings, Infrastructure and Energy), decorative paint was the largest in 2022, accounting for almost 36% of the total €2159 million in revenues. The recent annual reports by Hempel in 2020[65], 2021[66] and 2022[67] show that revenues from decorative paints have increased significantly in the last few years, going from €472 million in 2019 to €512 million in 2020 (+8.5%), to €655 million in 2021 (+28%) and then to €775 million in 2022 (+18.3%).

3.2.2 Factors affecting sales forecasts for decorative and architectural coatings

According to Allied Market Research[68], the global architectural coatings market is predicted to increase from global sales of $63300 million in 2020 to $107900 million in 2030, at a Compound Annual Growth Rate (CAGR) of 5.6%. Another estimate by Industry Research[69], for the global paints and coatings sector (architectural, traffic, wood, industrial equipment and others) estimates an increase from $203.4 million to $277.8 million at a CAGR of 4.5% between the years 2023 and 2029. In a forecast for the period 2020 to 2027, Grand View Research[70] used a figure of $146200 million in 2019 as a baseline, predicting global growth at a CAGR of 4.3% that would lead to sales of around $204749 million in 2027. Generally speaking, most organic growth in architectural is expected in the developing Asia-Pacific market via new construction and infrastructure, while trends in Europe will be more or less constant, being more influenced by refurbishment and renovation than new construction.

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63 See: https://report.akzonobel.com/2022/ar/business-overview/decorative-paints-emea.html

64 See: https://report.akzonobel.com/2022/ar/business-overview/decorative-paints-emea.html

65 See: https://www.hempel.com/en-sea/-/media/files/global/pdf/annual-report/hempel-annual-report-2020.pdf

66 See: https://www.hempel.com/-/media/Files/Global/PDF/Annual-Report/Hempel-Annual-Report-2021.pdf

67 See: https://www.hempelfonden.dk/media/2415/hempel-foundation-report-2022.pdf

68 See: https://www.coatingsworld.com/issues/2024-01-01/view_features/decorative-architectural-coatings/7877

69 See: https://www.linkedin.com/pulse/paints-coatings-market-2023-top-players/

70 See: https://www.grandviewresearch.com/industry-analysis/paints-coatings-market

Within the mature European market, increased demand for ecofriendly coatings is expected due to continued regulatory pressures.

It must be noted that the positive expected global growth rates are not necessarily representative of real organic[71] growth, especially regarding data for the last few years. Sales increases have also been strongly influenced by increases in product prices, which in turn are a reflection of increased raw material costs, increased energy costs and increased freight costs. In the case of the very rapid growth in sales revenues of the major global players in the decorative coatings sector mentioned in the last subsection, these figures are strongly influenced by both price increases and major acquisitions.

The primary market driver for organic growth is expected to come from an increasing consumption in construction, automotive, and other industry sectors and rapid urbanization and industrialization in countries, such as India, China, and Southeast Asia.

In many Western countries, the COVID lockdowns of 2020 led to increased sales of decorative paints in the DIY sector, as part of the cocooning effect of people spending more time at home and looking to improve their surroundings. However, that spike in sales was a one-off and dropped back in 2021-2022. Inflation and rapidly rising interest rates (from historic lows) have influenced consumer finances and, coupled with the energy crisis in Europe in 2021, have contributed to a cost-of-living crisis where spending on products like decorative paints takes secondary importance compared to paying energy bills, food bills and mortgage or rent payments.

Sales of decorative and architectural coatings are closely linked to movements in the construction and real estate sectors. Real estate activity goes hand in hand with painting, both to improve the aesthetics of buildings prior to going on the market, or to meet new occupant tastes after purchase or leasing. The broader architectural coatings category is heavily influenced by the production of construction products and materials needed for new construction and renovation projects. However, the rapid increase in interest rates and cost-of-living crisis has also had a negative effect on demand for new buildings in many parts of Europe.

3.3 Sales trends in the EU

Data derived from PRODCOM categories do not directly match the scope of EU Ecolabel for indoor and outdoor paint and varnish products but the data for relevant products gives a clear indication of trends in trade balances, sales values, sales volumes, unit prices and apparent consumption in the EU. The first step in such an analysis is to identify the most relevant PRODCOM codes.

3.3.1 PRODCOM analysis methodology

Since most of the detailed analysis takes place using data from the PRODCOM database in this section, it was considered necessary to explain in some detail the method used.

With PRODCOM data, it was decided to look at trends since 2007, in order to have a comparison to sales values (in millions of EUR) and volumes (in millions of kg) since before the global economic crisis of 2008. A total of 8 potentially relevant categories were identified.

Table 16. PRODCOM codes considered most relevant to the scope for EUEL paints and varnishes[72]

Code(s)	Description
20.30.11.50	Paints and varnishes, based on acrylic or vinyl polymers dispersed or dissolved in an aqueous medium (including enamels and lacquers).
20.30.11.70	Other paints, varnishes dispersed or dissolved in an aqueous medium.

[71] "Organic business growth is growth that comes from a company's existing businesses, as opposed to growth that comes from buying new businesses. It may be negative. Through growth planning, businesses are able to achieve organic growth by selecting the best strategies available to them. For example, businesses can select from market penetration, market development, product development and diversification to grow their revenue organically. In addition, organic business growth can be achieved using content marketing efforts, which drive organic search traffic."

[72] Source: Database - Prodcom - statistics by product - Eurostat (europa.eu); Dataset: Sold production, exports and imports [DS-056120, custom-8262303] - https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_8262303/default/table

Code(s)	Description
20.30.12.25	Paints and varnishes, based on polyesters dispersed/dissolved in a non-aqueous medium, weight of the solvent > 50 % of the weight of the solution including enamels and lacquers.
20.30.12.29	Paints and varnishes, based on polyesters dispersed/dissolved in a non-aqueous medium including enamels and lacquers excluding weight of the solvent > 50 % of the weight of the solution.
20.30.12.30	Paints and varnishes, based on acrylic or vinyl polymers dispersed/dissolved in non-aqueous medium, weight of the solvent > 50 % of the solution weight including enamels and lacquers.
20.30.12.50	Other paints and varnishes based on acrylic or vinyl polymers
20.30.12.70	Paints and varnishes: solutions n.e.c.[73]
20.30.12.90	Other paints and varnishes based on synthetic polymers n.e.c.

Source: Database - Prodcom - statistics by product - Eurostat (europa.eu); Dataset: Sold production, exports and imports [DS-056120, custom-8262303] - https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_8262303/default/table

EU27 Imports and exports: The first analysis with PRODCOM data looks at the relative strength of the internal market. This is assessed by comparing imports and exports to determine trends in the EU27 trade balance, and by looking at import and export data in comparison to domestic sold production. This first analysis is done with all eight PRODCOM categories combined.

PRODCOM aggregation: For the subsequent analyses of sales trends with PRODCOM data, it was decided to aggregate the 8 PRODCOM categories into 4, as detailed later in the section. The main reason for this was to make the visuals of the data presentation less cluttered.

Trends in domestic sold production: Data for EU27 level for each of the 4 aggregated PRODCOM categories is presented as stacked columns from the years 2007 to 2022, both in terms of value sold (PRODVAL) and quantity sold (PRODQNT). A closer look at the quantities of the water-based paints (the first 2 PRODCOM categories) is also presented at Member State level, focussing on data from 2014 and 2022. The % share of each Member State of EU27 in each year is mentioned, to show how values changed in % terms between 2014 and 2022.

Unit price trends: After presenting trends in sales, trends in unit prices were investigated. Average EU27 unit prices were generated simply by dividing sales values by sales volumes. Trends for EU27 unit prices for the 4 aggregated PRODCOM categories were reported in a line graph format for each year from 2007 to 2022. A closer look at how unit prices vary in the Member States for the 2 water-based PRODCOM categories is also presented in tabular format, looking at the years 2014 and 2022, as well as the % changes during that period.

Apparent consumption: Another feature of PRODCOM is that data is reported as "imported", "exported" and "own production". The apparent consumption for a given region and time period can thus be estimated by the following equation:

$$Apparent\ consumption\ = imports + own\ production - exports$$

The apparent consumption data from PRODCOM works well at EU level but can generate some strange-looking results at Member State level, such as negative apparent consumption values. This can occur if own production results are not properly segregated from export results. There is a higher risk of this happening when multi-national companies are moving products between sites in different Member States within the EU prior to them being sold in a different Member State from where they were produced. Furthermore, changes in population can be an important reason for changes in apparent consumption. To remove this variable from the equation, it is also necessary to divide the result by the population, thus generating a "per capita apparent consumption":

$$Per\ capita\ apparent\ consumption\ = \frac{imports + own\ production - exports}{population}$$

Trends in these values were reported at EU27 level over the period 2007 to 2022 for the 2 PRODCOM categories that correspond to water-based paints and varnishes.

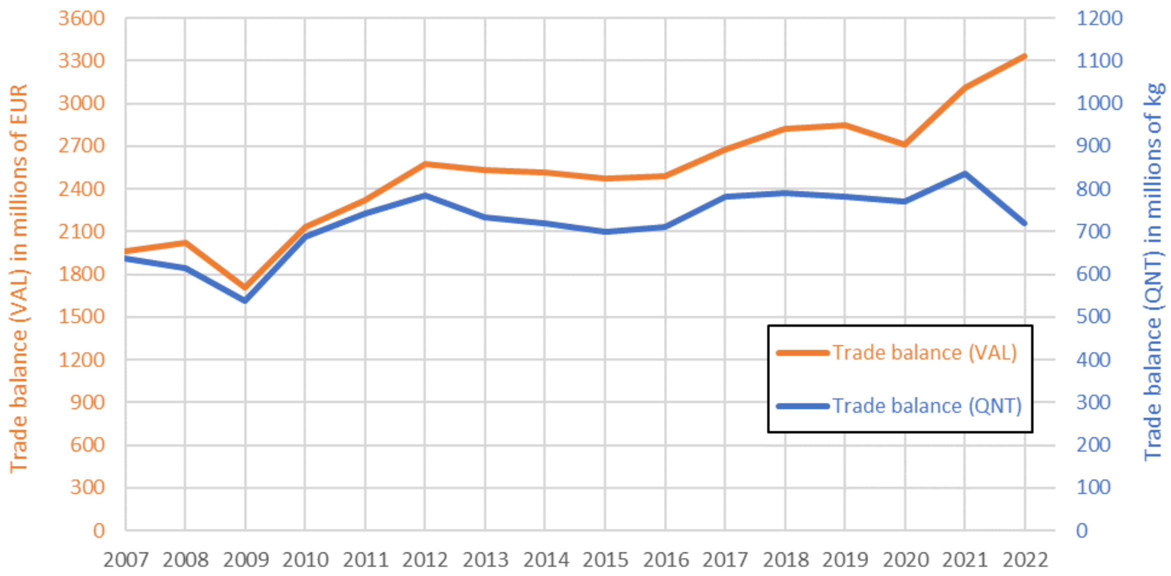
3.3.2 Imports and exports of paints and varnishes in the EU (trade balance)

The trade balance for any particular region over a defined period of time refers to the relative values for imports and exports (exports minus imports). Consequently, a positive trade balance refers to a case when exports are exceeding imports, and a negative trade balance refers to the opposite case. The figure below shows the trade

[73] n.e.c stands for not elsewhere classified

balance for the $EU27_{2020}$ since 2007 for the combined import and export data for the paint and varnish categories listed in the table above.

Figure 7. Trends in EU27 trade balance for paint and varnish products since 2007 (all 8 PRODCOM codes)



Source: [PRODCOM, 2023, https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_8262303/default/table](https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_8262303/default/table)

The figure above shows a consistently positive trade balance in the EU for paint and varnish products. In terms of the trade balance in value (VAL or value), the balance in 2007 was 1960 million € (2747 minus 787) and steadily rose to 3330 M€ in 2022 (4475 minus 1145). In terms of unit (QNT or quantity) the trade balance is also highly positive in 2007 (636 Mil. kg, 881 minus 244) and had grown to 721 Mil. kg (958 minus 237) by 2022.

The gradual widening of the gap between the VAL and QNT trade balances implies that the average unit price of exported products is increasing. This trend started around 2011 and has steadily grown for most years since then, with a major gap emerging in 2021. It remains to be seen if this recent and dramatic broadening of the gap was an artefact of the COVID lockdown restrictions or is the beginning of a longer-term trend.

It is also interesting to put import and export figures in the context of domestic EU27 production, as has been done in the table below. In general, exports were consistently 3-4 times higher than imports.

Table 17. EU27 data for imports exports and domestic production in value and quantity (EXPVAL, EXPQNT, IMPVAL, IMPQNT, PRODVAL and PRODQNT for the 8 PRODCOM codes).

Year	EXPQNT (% of PRODQNT)	IMPQNT (% of PRODQNT)	PRODQNT (millions kg)	EXPVAL (% of PRODVAL)	IMPVAL (% of PRODVAL)	PRODVAL (millions EUR)
2007	881 (12.0%)	244 (3.3%)	7312	2747 (16.1%)	787 (4.6%)	17047
2008	872 (12.4%)	257 (3.6%)	7059	2798 (17.6%)	773 (4.9%)	15931
2009	742 (11.9%)	205 (3.3%)	6260	2330 (16.5%)	627 (4.4%)	14152
2010	918 (13.9%)	230 (3.5%)	6588	2849 (18.4%)	713 (4.6%)	15461
2011	987 (15.2%)	245 (3.8%)	6496	3115 (18.9%)	797 (4.8%)	16459
2012	1032 (16.2%)	246 (3.9%)	6352	3432 (21.3%)	859 (5.3%)	16109
2013	986 (15.9%)	253 (4.1%)	6186	3378 (20.7%)	847 (5.2%)	16280
2014	980 (15.4%)	261 (4.1%)	6362	3386 (20.4%)	873 (5.3%)	16618
2015	963 (14.8%)	264 (4.1%)	6513	3380 (21.0%)	907 (5.6%)	16087
2016	973 (14.9%)	261 (4.0%)	6516	3366 (20.8%)	878 (5.4%)	16211
2017	1046 (15.9%)	263 (4.0%)	6573	3588 (20.9%)	909 (5.3%)	17208

Year	EXPQNT (% of PRODQNT)	IMPQNT (% of PRODQNT)	PRODQNT (millions kg)	EXPVAL (% of PRODVAL)	IMPVAL (% of PRODVAL)	PRODVAL (millions EUR)
2018	1049 (16.3%)	258 (4.0%)	6424	3748 (21.7%)	930 (5.4%)	17293
2019	1039 (17.1%)	256 (4.2%)	6073	3810 (23.0%)	961 (5.8%)	16548
2020	1022 (15.7%)	250 (3.8%)	6523	3609 (21.0%)	894 (5.2%)	17203
2021	1085 (16.2%)	249 (3.7%)	6676	4141 (22.0%)	1033 (5.5%)	18842
2022	958 (14.7%)	237 (3.6%)	6535	4475 (22.3%)	1145 (5.7%)	20074

Source: PRODCOM, 2023, https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_8262303/default/table

The data in the table above show that imports to the EU27 are and have been insignificant compared to domestic sold production (always <5% by quantity and <6% by value). Exports are notably more significant, as would be expected due to the positive trade balance of the EU in this sector. Exports have gradually become more significant compared to domestic sold production both in terms of quantity (rising from around 12% in 2007-09 to around 16% in 2017-21) and in terms of value (rising from around 16% in 2007-09 to around 21% in 2017-21).

3.3.3 Aggregation of PRODCOM categories for more focused analysis

The trends in sold production of relevant paint and varnish products since 2007 is illustrated in the next sub-sections. However, before presenting these figures, it should be explained that the eight PRODCOM codes identified in the methodology section have been condensed into four aggregated categories as follows:

Table 18. PRODCOM codes considered most relevant to the scope for EUEL paints and varnishes[74]

Code(s)	Description	New aggregated category and reason
20.30.11.50	Paints and varnishes, based on acrylic or vinyl polymers dispersed or dissolved in an aqueous medium (including enamels and lacquers).	Not aggregated, but shortened name of "Acrylic or vinyl polymer-based P&V, aqueous medium" is given. The most popular PRODCOM category amongst EU Ecolabel P&V.
20.30.11.70	Other paints, varnishes dispersed or dissolved in an aqueous medium.	Not aggregated, but shortened name of "Other P&V, aqueous medium" is given. These products are highly likely to fall within the scope of the EU Ecolabel.
20.30.12.25	Paints and varnishes, based on polyesters dispersed/dissolved in a non-aqueous medium, weight of the solvent > 50 % of the weight of the solution including enamels and lacquers.	Aggregated together and given the name "Polyester or acrylic-based P&V, organic solvent medium". None of these categories are expected to be applicable to the EU Ecolabel, but are included for context.
20.30.12.29	Paints and varnishes, based on polyesters dispersed/dissolved in a non-aqueous medium including enamels and lacquers excluding weight of the solvent > 50 % of the weight of the solution.	
20.30.12.30	Paints and varnishes, based on acrylic or vinyl polymers dispersed/dissolved in non-aqueous medium, weight of the solvent > 50 % of the solution weight including enamels and lacquers.	
20.30.12.50	Other paints and varnishes based on acrylic or vinyl polymers	Aggregated together and given the name "Other P&V n.e.c". Uncertain to which extent these products may be included in the scope of the EU Ecolabel, but counted anyway for context.
20.30.12.70	Paints and varnishes: solutions n.e.c.	
20.30.12.90	Other paints and varnishes based on synthetic polymers n.e.c.	

Source: Combination of Eurostat PRODCOM and own elaboration.

The first two categories that refer only to water-based paints are not aggregated. The next three categories in the table above have been aggregated since they are all linked to organic solvent-based formulations, which contain at least 50% organic solvent in two of the codes and up to 50% in the last. Due to the high VOC content of organic solvent, these categories cannot be included in the scope of the EU Ecolabel for paints and varnishes, where the Ecolabel limit for VOCs is between 1 and 8% depending on the product category, and thus far lower

[74] Source: Database - Prodcom - statistics by product - Eurostat (europa.eu); Dataset: Sold production, exports and imports [DS-056120, custom-8262303], https://ec.europa.eu/eurostat/databrowser/view/ds-056120__custom_8262303/default/table

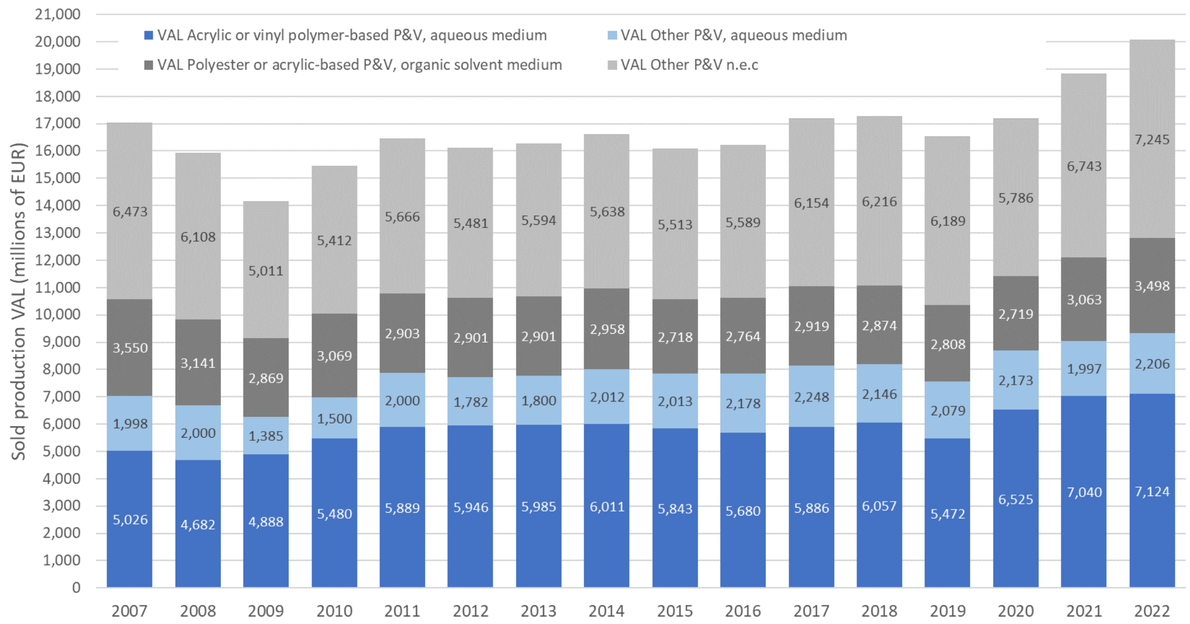
than the 50%. Consequently, it is not necessary to see a breakdown of this data, and it is only included in order to put the sales of water-based formulations in context.

The final three categories in the table above have also been aggregated since they all refer to "other" and, given the title of the second category in the table above, it seems unavoidable that these "other" paints are not water-based formulations – a thus unlikely to be relevant to the scope for EU Ecolabel paints and varnishes. However, as with organic solvent-based products, data is included at least to provide context for the sales for water-based products.

3.3.4 Sales value trends for EU production (PRODVAL)

In the figure below, the blue columns represent those paint categories that are water based (aqueous medium) and are thus very likely to fall within the scope for EU Ecolabel criteria. The dark grey column refers to organic solvent-based paints and varnishes that can be assumed to not meet the requirements of the EU Ecolabel scope. The light grey column refers to "other" paint categories which are unlikely to fall within the scope of the EU Ecolabel since they are likely to have significant VOC contents. The trends for these four aggregated categories of paint and varnish products are shown below during the period 2007 to 2022.

Figure 8. Sold production value (PRODVAL) of EU27 for different aggregated categories of paint and varnish products during the period 2007 to 2022.



Source: Combination of Eurostat PRODCOM and own elaboration.

As can be seen in the figure above, the sold production value for water-based paints and varnishes (the two blue columns) decreased between 2007 and 2009, no doubt due to the global economic crisis. However, sales values began to recover in 2010 and remained stable during the 2010 to 2018. A dip was experienced in 2019 followed by a strong increase in the years 2020 to 2022 for the water-based acrylic and vinyl polymer products.

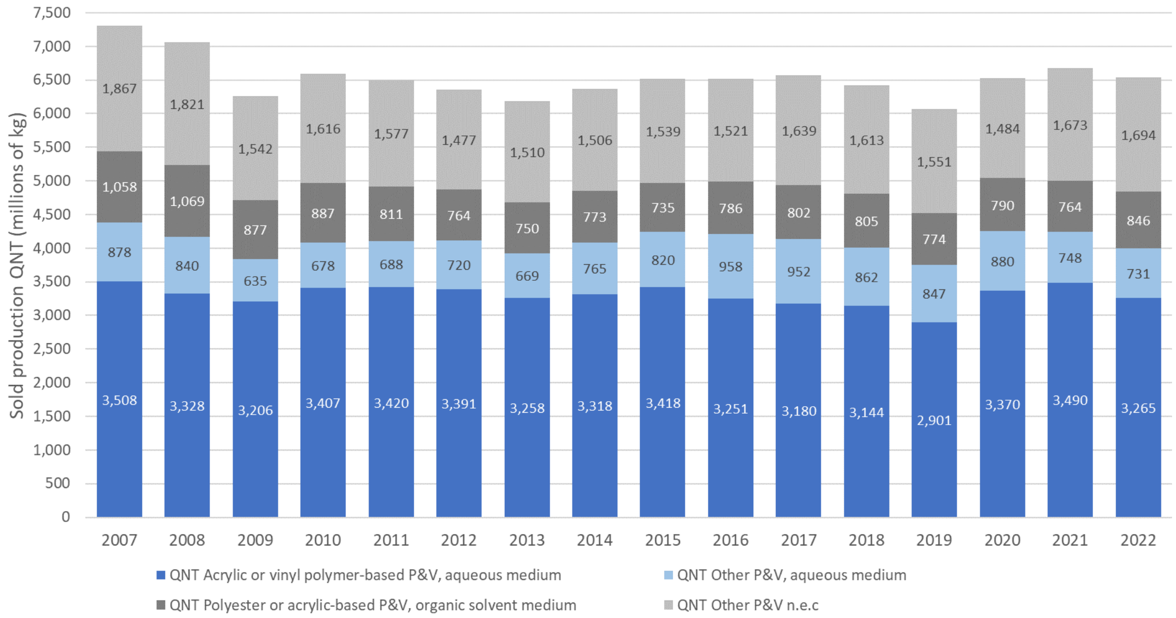
With the organic solvent-based products (dark grey columns) and also the "other" categories, sales followed a very similar pattern to those for the water-based acrylic and vinyl polymer paints and varnishes.

Given that significant inflation has also occurred during the period 2007 to 2022, it is worth checking how sold production quantities (PRODQNT) have evolved during the same period.

3.3.5 Sales quantity trends for EU and Member State production (PRODQNT)

Following the same data analysis and presentation as presented above for PRODVAL, the results for PRODQNT are illustrated in the figure below.

Figure 9. Sold production quantity (PRODQNT) of EU27 for different aggregated categories of paint and varnish products during the period 2007 to 2022.



Source: Combination of Eurostat PRODCOM and own elaboration.

The trends in PRODQNT mirror quite closely the trends observed already for PRODVAL. This means that there was a reduction in sold quantities in between 2007 and 2009, a recovery in 2010, a stable period from 2011 to 2018, a dip in 2019 and then a significant increase in the years 2020 to 2022. The only clear difference in trends was the 2022 data, which showed water-based acrylic and vinyl polymer decreasing in PRODQNT, but slightly increasing in PRODVAL.

At Member State level: In order to check how the sold production quantities (PRODQNT) of water-based paints and varnishes is distributed with the EU Member States, data for each country from 2014 and 2022 are provided in the table below. The two years were chosen because they represent the year when the current EU Ecolabel criteria were adopted and the most recent full year of PRODCOM data. The data in the table below is ordered in terms of highest sales quantities of water-based acrylic or vinyl polymer paints and varnishes in 2014. Any significant reductions or increases in production quantities between 2014 and 2022 (i.e. more than 10%) are highlighted in red or green text.

Table 19. Production quantities (PRODQNT) for water-based paints at Member State level in 2014 and 2022.

	Acrylic or vinyl polymer (water-based)					Other paints and varnishes (water-based)				
	2014 QNT (Mil. kg)	2014 (% of EU)	2022 QNT (Mil. kg)	2022 (% of EU)	% change from 2014 to 2022	2014 QNT (Mil. kg)	2014 (% of EU)	2022 QNT (Mil. kg)	2022 (% of EU)	% change from 2014 to 2022
DE	939.7	28.3%	759.9	23.2%	-19.1%	204.1	27.7%	208.5	28.6%	2.2%
FR	547.5	16.5%	483.7	14.8%	-11.6%	19.9	2.7%	24.0	3.3%	20.9%
IT	399.7	12.0%	499.4	15.3%	24.9%	157.7	21.4%	112.1	15.4%	-28.9%
PL	313.3	9.4%	232.4	7.1%	-25.8%	16.0	2.2%	43.5	6.0%	171.6%
ES	278.7	8.4%	409.2	12.5%	46.8%	164.2	22.3%	140.4	19.3%	-14.5%
NL	125.8	3.8%	111.6	3.4%	-11.3%	8.8	1.2%	12.1	1.7%	37.5%
SE	124.5	3.8%	130.3	4.0%	4.7%	15.0	2.0%	19.8	2.7%	31.8%
PT	84.8	2.6%	89.2	2.7%	5.3%	3.5	0.5%	3.9	0.5%	12.3%
HU	75.7	2.3%	77.2	2.4%	2.0%	0.3	0.0%	0.2	0.0%	-50.9%
RO	68.7	2.1%	103.7	3.2%	50.8%	38.1	5.2%	80.6	11.1%	111.6%
EL	62.8	1.9%	86.8	2.7%	38.3%	1.1	0.1%	6.2	0.8%	464.7%

	Acrylic or vinyl polymer (water-based)					Other paints and varnishes (water-based)				
	2014 QNT (Mil. kg)	2014 (% of EU)	2022 QNT (Mil. kg)	2022 (% of EU)	% change from 2014 to 2022	2014 QNT (Mil. kg)	2014 (% of EU)	2022 QNT (Mil. kg)	2022 (% of EU)	% change from 2014 to 2022
FI	52.8	1.6%	54.8	1.7%	3.8%	7.7	1.0%	5.5	0.8%	-28.9%
CZ	49.1	1.5%	42.4	1.3%	-13.5%	34.3	4.7%	32.7	4.5%	-4.7%
DK	45.5	1.4%	40.8	1.2%	-10.3%	6.3	0.9%	13.8	1.9%	117.2%
AT	45.0	1.4%	43.2	1.3%	-3.9%	13.4	1.8%	12.8	1.8%	-4.2%
BE	34.4	1.0%	25.3	0.8%	-26.6%	4.8	0.7%	5.0	0.7%	3.6%
BG	16.7	0.5%	13.8	0.4%	-17.0%	21.6	2.9%	6.0	0.8%	-72.2%
IE	15.2	0.5%	14.5	0.4%	-4.4%	0.0	0.0%	0.0	0.0%	
HR	12.1	0.4%	21.6	0.7%	78.1%	12.3	1.7%	0.1	0.0%	-99.5%
EE	10.2	0.3%	8.6	0.3%	-16.2%	0.1	0.0%	0.1	0.0%	3.8%
LT	6.3	0.2%	7.5	0.2%	19.0%	0.3	0.0%	0.5	0.1%	74.2%
SI	5.9	0.2%	12.2	0.4%	106.3%	0.0	0.0%	0.0	0.0%	
SK	3.3	0.1%	2.1	0.1%	-37.1%	6.1	0.8%	1.4	0.2%	-77.4%
LV	0.5	0.0%	2.4	0.1%	393.8%	0.0	0.0%	0.0	0.0%	
LU	0.0	0.0%	0.0	0.0%		0.0	0.0%	0.0	0.0%	
MT	0.0	0.0%	0.0	0.0%		0.0	0.0%	0.0	0.0%	
CY	0.0	0.0%	0.0	0.0%		0.0	0.0%	0.0	0.0%	
EU27	3318.1	100%	3272.5	100%	-1.4%	735.4	100%	728.9	100%	-0.9%

Source: Combination of Eurostat PRODCOM and own elaboration.

Acrylic and vinyl polymer paints: The table above shows that at EU level, there was a slight decrease in total production quantities between 2014 and 2022 (-1.4%). The most populated EU countries (i.e. DE, FR, IT, PL and ES) dominated the production of this category of paints and varnishes, accounting for around 75% of EU27 production in 2014, and still around 73% of production in 2022. However, this apparent stability masks some significant decreases in DE, FR and PL and significant increases in IT and ES. The increases in IT and ES represent large production quantities (around 230 million kg between them).

It is also worth mentioning some highly significant relative increases in production in some Member States, especially Latvia (almost a 5-fold increase between 2014 and 2022), Slovenia with a more than 2-fold increase and Croatia with an almost 2-fold increase.

Other water-based paints: The total quantities of this category of paints at EU level are around four times less than the acrylic or vinyl polymer category and decreased slightly (-0.9%) between 2014 and 2022 at EU level. In terms of most significant producing Member States, the trend is somewhat different to the acrylic or vinyl polymer paints in the sense that FR and PL have much more modest shares of production (3.3% and 6.0% in 2022, respectively). Around 74% of EU production in 2022 was concentrated in four Member States, DE, ES, IT and RO.

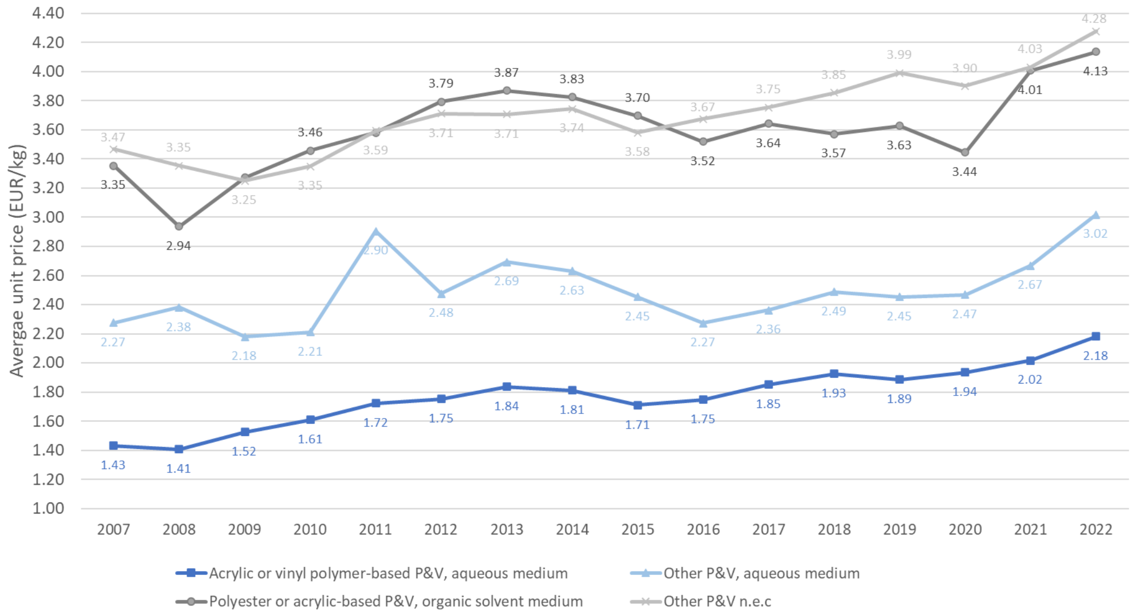
The biggest relative increases at Member State level between 2014 and 2022 were observed in Greece (almost 6-fold increase), Poland (almost 3-fold increase), Denmark (more than 2-fold increase), Poland (more than 2-fold increase) and Lithuania (almost 2-fold increase).

It should be noted that, looking at the data for Croatia in particular, the big increase in acrylic or vinyl polymer products is accompanied by an almost equally big decrease in the “other” category – implying that the 2014 data for “other” production may have been miscategorised in 2014 and corrected by 2022.

3.3.6 Unit price trends for EU and Member State production (PRODVAL/PRODQNT)

At EU level for domestic production over time: The next logical step is to combine the PRODVAL and PRODQNT data to generate average unit prices for each product category and year at EU27 level. Dividing PRODVAL data by PRODQNT data generates results in EUR/kg, as shown below.

Figure 10. EU27 average unit prices (in EUR/kg) for different aggregated categories of paint and varnish products during the period 2007 to 2022.



Source: Combination of Eurostat PRODCOM and own elaboration.

The data above reveal that the water-based formulations are significantly cheaper (around 33% to 50% cheaper) on a per kg basis than the organic solvent-based formulations. The most obvious reason for this can be considered to relate to water being cheaper than organic solvents. Amongst the two water-based categories, the results were consistently cheaper for the more commonly produced acrylic or vinyl polymer paints and varnishes. This is most likely due to the larger volumes produced also being associated with larger production lines and associated economies of scale.

The fact that unit prices are growing significantly for all paint categories since 2020 implies that it is inflation that is indeed behind the recent increase in PRODVAL and not increased consumption or demand for paint in the EU27. Whether or not this inflation was triggered solely by COVID lockdowns in 2020 or the sudden increases in wholesale gas and electricity prices in most of the EU remains to be seen.

At Member State level for domestic production: In order to check how the unit prices of water-based paints and varnishes is distributed with the EU Member States, data for each country from 2014 and 2022 are provided in the table below. The two years were chosen because they represent the year when the current EU Ecolabel criteria were adopted and the most recent full year of PRODCOM data. The data in the table below is ordered in terms of highest unit prices of water-based acrylic or vinyl polymer paints and varnishes in 2014. Any significant increases or reductions in unit prices between 2014 and 2022 (i.e. more than 10%) are highlighted in red or green text.

Table 20. Unit prices (PRODVAL/PRODQNT) for domestically produced water-based paints at Member State level in 2014 and 2022.

	Acrylic or vinyl polymer (water-based)			Other paints and varnishes (water-based)		
	2014 €/kg	**2022 €/kg**	% change	**2014 €/kg**	**2022 €/kg**	% change
Belgium	4.10	4.11	0.2%	9.62	7.08	-26.4%
Finland	2.88	3.29	14.0%	2.69	3.59	33.5%
Sweden	2.61	3.20	22.8%	4.50	5.35	18.8%
Austria	2.49	3.21	28.9%	3.23	4.26	32.0%
France	2.47	2.61	5.9%	3.26	4.50	38.2%
Ireland	2.30	2.35	2.1%	no data	no data	no data
Denmark	2.27	2.73	20.3%	3.49	3.09	-11.5%
Italy	2.23	2.34	4.8%	2.90	3.71	27.7%
Netherlands	2.12	3.68	73.7%	5.91	6.43	8.7%

	Acrylic or vinyl polymer (water-based)			Other paints and varnishes (water-based)		
	2014 €/kg	**2022 €/kg**	% change	**2014 €/kg**	**2022 €/kg**	% change
Portugal	1.77	2.17	22.8%	2.71	3.12	15.3%
Greece	1.67	1.61	-3.7%	3.13	2.47	-21.0%
Estonia	1.62	2.05	26.9%	1.80	1.67	-6.8%
Germany	1.54	2.10	36.6%	4.02	4.22	4.8%
Slovenia	1.39	1.53	10.2%	no data	no data	no data
Slovakia	1.36	1.42	4.2%	1.41	1.52	8.3%
Spain	1.25	1.51	21.4%	1.67	1.59	-4.9%
Latvia	1.23	1.50	21.9%	no data	no data	no data
Poland	1.15	1.43	24.2%	1.69	2.24	32.6%
Lithuania	1.08	1.48	36.2%	0.81	1.29	59.9%
Czechia	0.92	1.42	53.9%	0.56	0.93	66.6%
Romania	0.80	1.18	47.3%	0.91	1.09	19.7%
Hungary	0.74	1.11	50.9%	3.31	5.28	59.3%
Bulgaria	0.73	1.41	92.4%	0.59	1.00	70.4%
Croatia	0.68	0.93	37.7%	0.62	4.53	631.6%
Cyprus	zero	zero	zero	zero	zero	zero
Malta	zero	zero	zero	zero	zero	zero
Luxembourg	zero	zero	zero	zero	zero	zero
EU27	1.81	2.18	20.5%	2.63	3.02	14.7%

Source: Own elaboration

Acrylic and vinyl polymer paints: The table above shows that at EU level, there was a significant increase in unit prices of 20.8% between 2014 and 2022. With the notable exception of Greece (-3.7%), unit prices increased to a greater or lesser extent in all Member States during the same time period.

In 2014, the difference in unit prices at Member State level varied by more than a factor of 5 between the cheapest (Croatia at 0.68 €/kg) and the most expensive (Belgium at 4.10 €/kg). In 2022, this difference between cheapest and most expensive had narrowed to a factor of around 4.5 (still Croatia, now at 0.93 €/kg, and Belgium, now at 4.11 €/kg). It was not clear why the unit prices in Belgium were so high. The biggest relative increases in unit prices between 2014 and 2022 occurred in Bulgaria (+92.4%) and the Netherlands (+73.7%). Many other Member States showed relative increases of more than 30% as well.

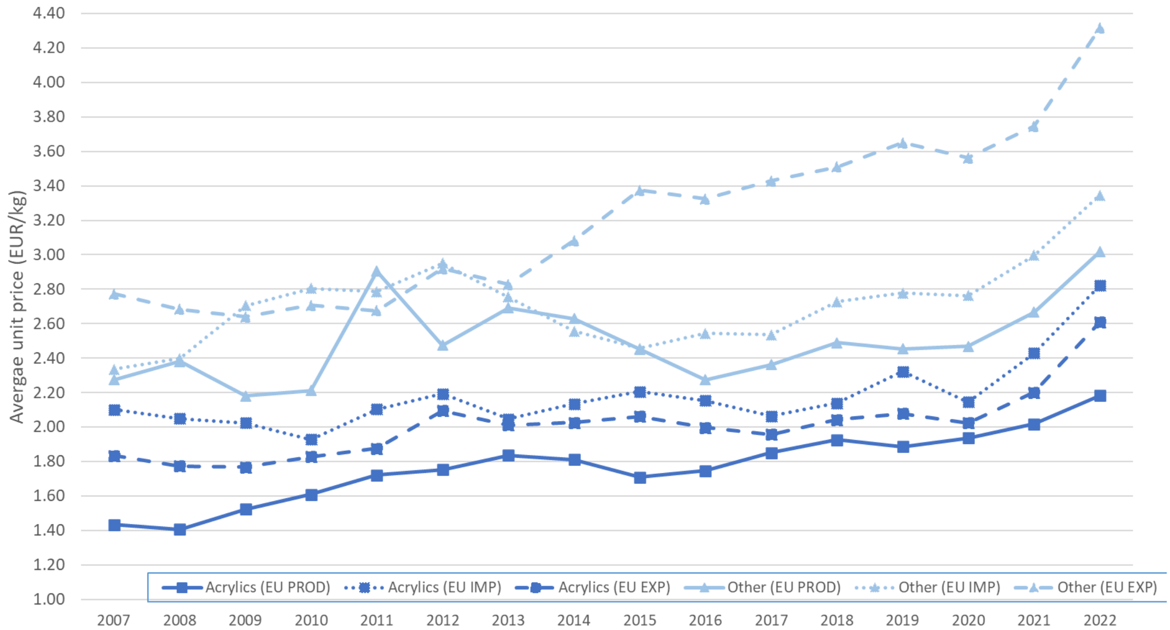
Other water-based paints: At EU level there was also a significant increase in average unit prices of 14.7% between 2014 and 2022. However, while unit prices increased to a large extent in some Member States, they also decreased in several others. The most notable decreases were in Belgium (-26.4%), Greece (-21.0%) and Denmark (-11.5%). The reasons for these decreases are unclear, but probably relate to the cessation of production of more expensive types of "other" water-based paints.

In 2014, the difference in unit prices at Member State level varied by more than a factor of 15 between the cheapest (Czechia at 0.56 €/kg) and the most expensive (Belgium at 9.62 €/kg). In 2022, this difference between cheapest and most expensive had narrowed to a factor of around 7.5 (still Czechia, now at 0.93 €/kg, and Belgium, now at 7.08 €/kg). Ignoring the presumably erroneous data from Croatia (+632%), the biggest relative increases in unit prices between 2014 and 2022 occurred in Bulgaria (+70.4%), Lithuania (+59.9%) and Hungary (+59.3%).

3.3.7 Unit price trends for EU production versus import and export unit prices

Although the EU has a steadily positive trade balance for paint and varnish products, it is worth looking at the average unit prices for imported and exported products compared to the unit prices for domestically produced and consumed products. Unit price data and trends for the two water-borne categories ("acrylic or vinyl polymer, water-based" and "other, water-based") are presented in the figure below.

Figure 11. Trends in average EU27 unit prices (in EUR/kg) for domestically produced and consumed water-borne paints (EU PROD), for imports of the same (EU IMP) and exports of the same (EU EXP) during the period 2007 to 2022.



Source: Combination of Eurostat PRODCOM and own elaboration.

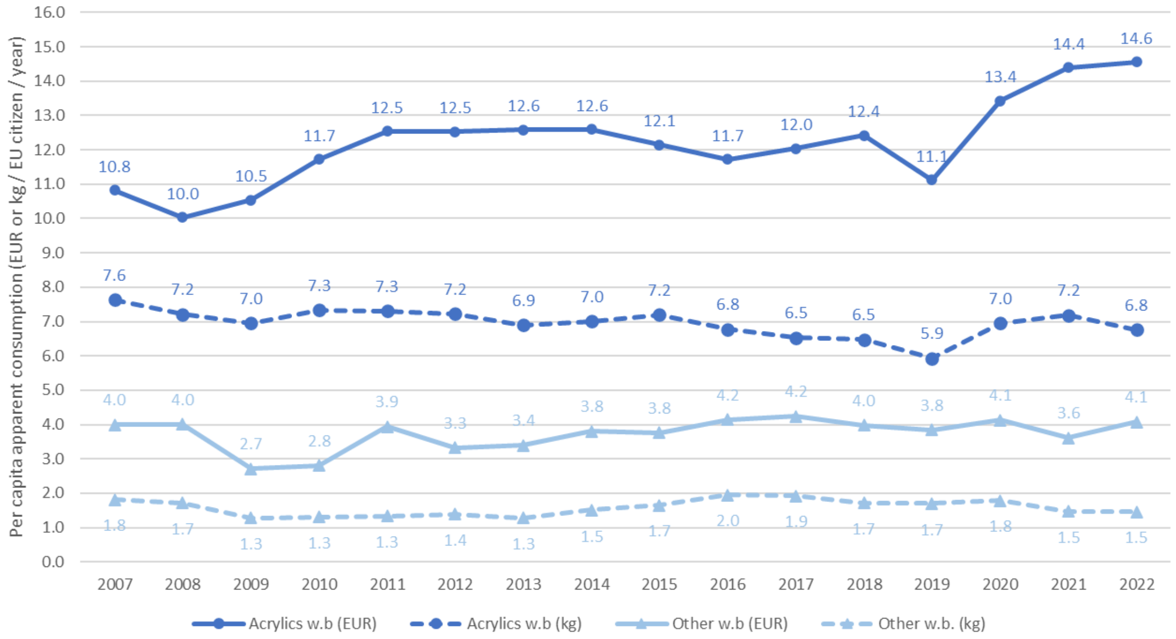
The general trend in the figure above shows that unit prices for all the products have increased during the 2014 to 2022 period and that "other" water-borne paints are generally more expensive. The darker blue lines (acrylic and vinyl polymer) are consistently lower than the lighter blue lines (other water-based paints and varnishes).

It is interesting to note that the domestically produced and consumed products (solid lines) are generally cheaper than both imported or exported products (dotted and dashed lines). From the fact that unit prices are higher for both imports and exports, and for both types of water-based paint, it can be implied that transport and storage costs are significant contributors to unit cost.

3.3.8 Per capita apparent consumption EU

The way to calculate per capita apparent consumption has already been explained in the methodology section. The trends for both "Acrylics or vinyl polymer, water-based paints and varnishes" and "Other water-based paints and varnishes" is presented below for EU27.

Figure 12. Trends in average EU27 per capita annual apparent consumption of water-borne paints, in terms of EUR and in terms of kg, during the period 2007 to 2022.



Source: Combination of Eurostat PRODCOM and own elaboration.

The most recent data in the figure above show that in 2022, the average per capita expenditure on water-based acrylic or vinyl polymer paints is 14.6 EUR, which is associated with 6.8 kg of this product category. Other water-based paints were less significant, accounting for 4.1 EUR and 1.5 kg.

For the acrylic or vinyl polymer paints and varnishes, the increase in sales values between 2008 and 2011, and between 2019 and 2022, are clearly associated with increases in unit prices. The increases in the 2019 to 2022 period are likely to be strongly influenced by the COVID lockdown restrictions in 2020 and the energy price crisis in the EU in 2021.

In terms of quantities consumed in the EU, there has been a slight decrease between 2007 and 2022 for both categories of water-borne paint and only relatively minor oscillations in values during this period.

3.4 Consumer preferences and uptake of the EU Ecolabel

The EU Ecolabel is essentially a marketing tool to help inform customers who want to make "green" purchasing decisions and businesses who want to show their commitment to sustainability. In this section, some recently published consumer-focused studies on paints are described in order to flag the issues that are considered as being most to consumers. Then trends in the uptake of the EU Ecolabel are described.

3.4.1 Recent consumer studies

3.4.1.1 Hungarian studies

The Conscious Consumer Association (Tudatos Vásárlók) published results of a study of off-the-shelf paint products in 2022 on their website[75]. The Hungarian study scored a total of 19 white interior wall paints according to the following criteria and weightings:

- Spreading rate (40% of score): the amount of material required to deliver a minimum standard opacity, which may require more than one layer. It was not clear exactly how this was scored.
- Wet scrub resistance (40% of score): a proxy measure defined in EN ISO 11998 of the durability of the coating and how easily it can be cleaned without deteriorating. Scores were either 40%, 32%, 24%,

[75] See here: https://tesztek.tudatosvasarlo.hu/feher-belteri-falfestekek/ (in Hungarian, machine translation used to interpret content)

16% or 8% depending on whether Class 1, 2, 3, 4 or 5 results according to EN 13300 were obtained (Class 1 being the most durable).

- Preservatives (10% of score): a simplified assessment of the presence or absence of any isothiazoline groups in the product measing either 0% or 10% is obtained.
- Label information (10% of score): Measures whether or not information was provided on 5 vital aspects, which were composition (2%); VOC content (2%, or 1% if only stating compliance with the upper legal limit); number of layers (2%); drying time (2%) and dilution (2%). If the information was not available in Hungarian, 0.5% was deducted.

Of the top 8 paints, 5 had been awarded either the Blue Angel or EU Ecolabel. It is also worth mentioning that among the 19 interior white wall paints, 14 were of the dispersive category, 4 were lime paints and 1 was a chalk paint. Judging by the ratings presented, it appeared that 8 of the 19 paints were free of isothiazoline preservatives.

While lime paints scored well with regards to preservatives (they do not need them due to their inherent high pH), they scored much lower in terms of durability, due to low wet scrubbing resistance. The article repeatedly mentions the importance of VOC content, but did not actually score it in this evaluation exercise. However, the did look at the VOC content of 23 interior white paints in a 2019 evaluation exercise[76], which looked at the following aspects:

- VOC content (g/L): compared against the legal limit of 30 g/L. A 70% weighting.
- Formaldehyde emissions (mg/m3): compared to an occupational health limit of 0.6mg/m3. A 20% weighting.
- Presence of isothiazolines: a 10% weighting.

The study found that VOC contents were well below the legal maximum of 30 g/L for this category of paint, but that there was a large variation between the paints tested (a 70-fold difference with results between 0.04 and 2.79 g/L). An even bigger variation was found in formaldehyde emissions (a 500 fold difference with results between 0.006 and 2.83 mg/m3). The higher results are especially important because these clearly exceeded the occupational health limit of 0.6 mg/m3. One paint that claimed to be “formaldehyde-free” did actually emit detectable quantities of formaldehyde, according to the study.

3.4.1.2 French studies

The French consumer association “60 millions de consommateurs” has published articles about two studies relating to paints in the last few years that are relevant to this section. One article published in March 2018[77] focused on the content of isothiazolines in paints (especially MethylIsoThiazoline, MIT, and BenzoIsoThiazoline, BIT) and cited a number of concerns about allergies and dermatitis in consumers being caused by this substance. The shift of industry away from parabens has led to an increase in the use of isothiazolines.

The article quoted that an estimated 2 to 4% of the French population are “sensitized” to MIT and also mentioned concerns about the use of isothiazolines not just in paints, but in cosmetics and hygiene products. Very low concentrations (e.g. just 5 ppm) can be enough to trigger allergic reactions in sensitised people. Of the 48 indoor white wall paints tested, they found MIT in 93% of products and BIT in 96%. and in concentrations that varied by an order of magnitude with the highest result being around 400 ppm. Another concern was that a number of products where isothiazolines were being detected did not correctly warn of their presence on packaging, even though this is a legal requirement.

It was also claimed that isothiazolines can be detected in VOC emissions from paints, meaning that there is another route of exposure even for people not applying the paint or even touching the painted surface. Some 13 paints were also tested for VOC emissions and results seemed to align with the VOC emission classes appearing on product labels (mandatory in France). The article did make some criticism of the low level of

[76] See here: https://tesztek.tudatosvasarlo.hu/feher-belteri-falfestekek-2019/ (in Hungarian, machine translation used to interpret content)

[77] See here: https://www.60millions-mag.com/2018/02/26/peintures-gare-la-mit-puissant-allergene-11622 (in French, machine translation used to interpret content). Actual article cited can be found here: https://boutique.60millions-mag.com/60millions/535

distinction made by the A+ VOC label, stating that it should be more ambitious. They also questioned if it would be better to look at results after shorter periods than 28 days as well, since concentrations can sometimes be very high at this point and it is a relevant exposure, especially for professional painters.

The second French study, described in the June 2023[78] edition of 60 millions de consommateurs, focused on claims made in paints with regard to biobased content for 14 interior white paints, 7 satin formulations and 7 matt formulations. A number of concerns were raised:

- Biobased content has a certain perception of being less toxic, but this is not necessarily the case – the exact same chemicals can be manufactured from biobased sources as from petrochemical ones.
- Following from the first point, the big difference in VOC emissions was dependent on the type of paint (e.g. matt versus satin) and not on whether or not it was biobased.
- There are no rules on how much biobased carbon has to be in a product before the biobased claim is made. Paints can have very low carbon contents (e.g. as low as 1%), but if that carbon is biobased, the whole product can carry the biobased claim – it would be misleading.

The article also looked at other issues apart from biobased claims, which were as follows:

- Label information on the presence of preservatives was not correct in many cases, and this could perhaps be due to a lack of knowledge of paint manufacturers on preservatives already present in the raw materials they receive.
- The use of TiO2 nanoparticles is synonymous with air purification claims, but the photocataltytic effect to break down VOCs might also generate new, smaller VOCs that might be more toxic than the precursor VOC. Further research needed. TiO_2 content was found to be much higher (ca. 30%) in satin paints.
- Testing revealed that packaging claims on the spreading rate are generally underestimated by manufacturers in order to sell more product.
- VOC contents should be considered in the context of the number of coats required and not just in terms of g/L.

The article also provided a renewed criticism of the French VOC label ambition level for the A+ level, stating that the limit for total VOCs should be lowered from 1000 to 50 mg/m3 in order to truly distinguish ultra-low VOC products on the market.

3.4.1.3 Uptake of the EU Ecolabel

Apart from the core issues of cost and performance, the consumer issues from the Hungarian and French studies emphasised that VOC content and the presence of hazardous substances is a major concern for consumers because of the potential adverse contribution they can make to indoor air quality. There are also concerns about the adequacy of information appearing on packaging regarding these aspects. Consequently, there is some added value for consumers in having products that have been certified by independent third parties as being good for the environment and with limited concentrations of harmful substances.

The EU Ecolabel, being an example of an ISO 14024 Type I ecolabel, is the best-known such ecolabel in the EU and has criteria developed specifically for paint and varnish products that were adopted in 2014. The current scope of the EU Ecolabel criteria for paints and varnishes is limited mainly to architectural coatings, and more specifically to decorative paints, varnishes and woodstains, including:

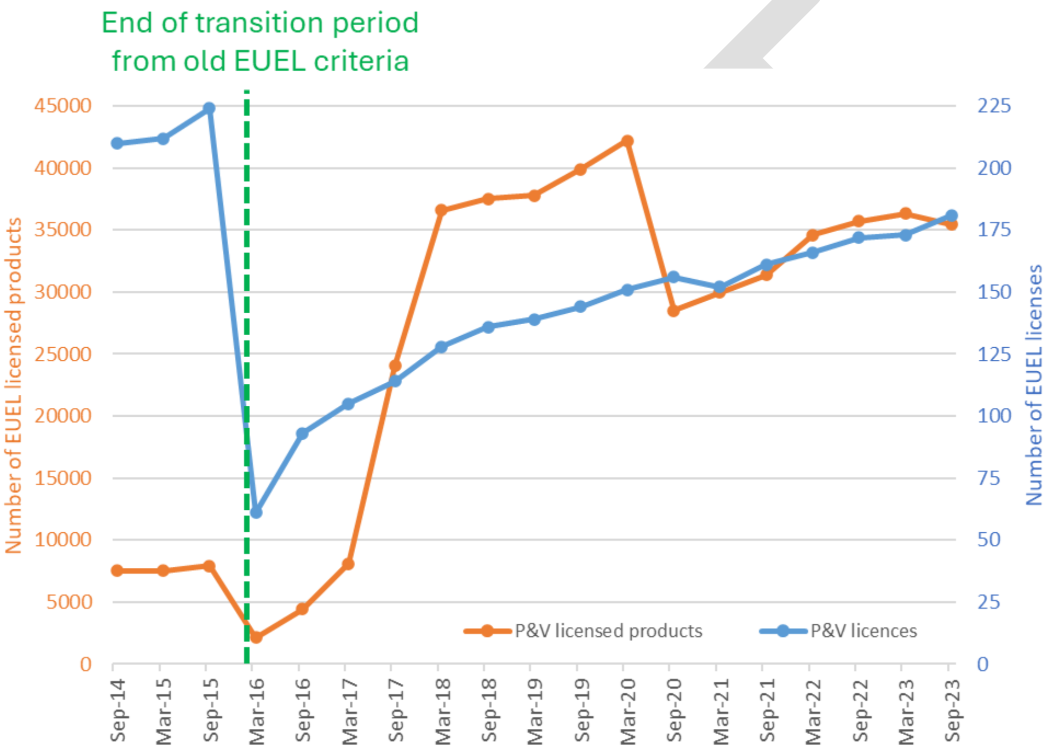
- Products for indoor or outdoor use.
- Floor coatings and floor paints.
- Base (white) paints used in tinting systems.
- Tints used in tinting systems.
- Products in liquid or paste format.
- Wood paints, wood and decking stains.
- Metal finishes, primers and undercoats.
- One-pack and two-pack performance coatings.

[78] See here: https://boutique.60millions-mag.com/60millions/592 (in French, machine translation used to interpret content).

Although exact data in terms of sales values and volumes of EU Ecolabel paints is not available, data on the number of licenses granted to paint and varnish producers, as well as the number of products covered by these licenses, is collected every 6 months by the EU Ecolabel helpdesk service.

The current EU Ecolabel criteria were adopted in May 2014, repealing the previous criteria sets that had been adopted in 2009 and which were set out in two Decisions, one for indoor paints and varnishes (Decision 2009/544/EC[79]) and one for outdoor paints and varnishes (Decision 2009/543/EC[80]). There was a 21-month transition period lasting up until February 2016 when products could be licensed in line with the 2009 criteria or the new 2014 criteria.

Figure 13. Trends in the uptake of EU Ecolabel paint and varnish products in the EU since 2014.



Source: EU Ecolabel statistics – European Commission[81].

Number of licenses and licensed products: As can be seen in the figure above, the 2009 EU Ecolabel criteria had reached around 225 licenses that covered around 7500 products. When the 2014 criteria came fully into force, there was a sudden drop in licenses (ca. -73%, from 225 to around 60) and licensed products (ca. -73%, from 7500 to 2000). The number of licenses has since steadily increased, as has the number of licensed products carrying the EU Ecolabel. License numbers did not recover to the same levels associated with the previous EUEL criteria, but the amount of licensed products are at least 4 times higher under the current criteria than the previous criteria.

These trends imply that the current criteria can be met by a significant number of producers and that each EU Ecolabel license is now being associated with a greater number of products than before. This may imply that larger companies with more extensive product catalogues are occupying a greater share of EU Ecolabel license holders.

There was a sudden drop in licensed products in 2020 (ca. -33%, from 42000 to 28000). While there has been some recovery since then, it has only been about halfway. This drop in licensed products was generally explained by industry stakeholders to be related to the need to adjust formulations due to CLP reclassifications of

[79] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009D0544

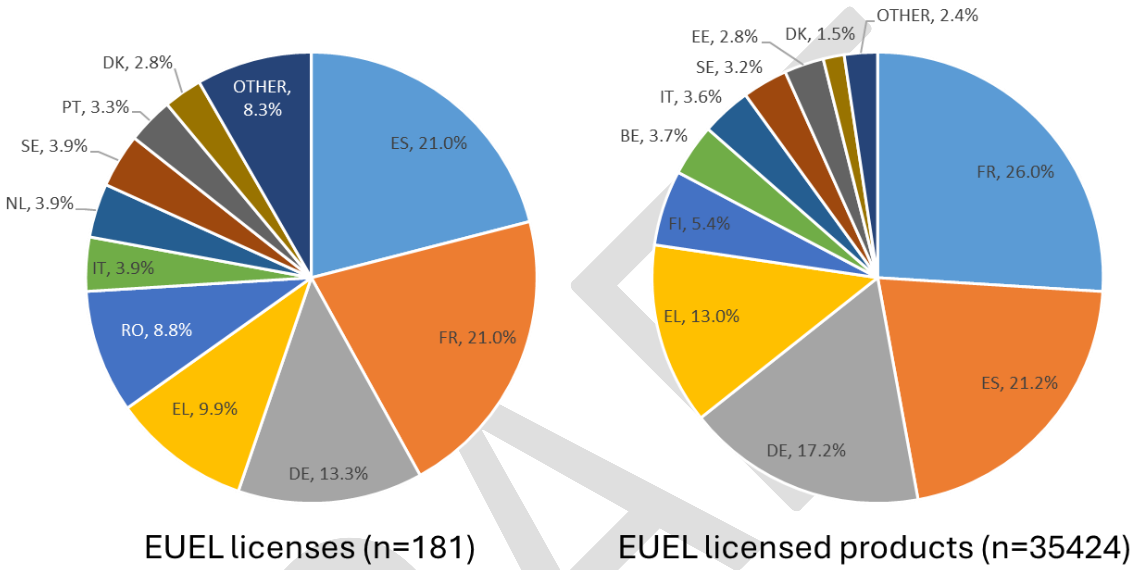
[80] See: https://eur-lex.europa.eu/eli/dec/2009/543/oj

[81] See: EU Ecolabel Statistics – European Commission: https://ec.europa.eu/environment/ecolabel/facts-and-figures.html

commonly used in-can and dry-film preservatives. Not all products could be reformulated in such a way that continued to respect the EUEL criteria, and that is the main reason why current licensed products in 2023 are still around 7000 lower than 2020 levels.

Where are licenses being awarded? How licenses and licensed products are distributed by awarding Competent Body is shown in the figure below. It should be noted that just because a license is awarded by one Member State, it can still be sold in any other Member State due to the single market principles of the EU. However, these shares give an indication of the level of experience of different Competent Bodies with the current EUEL criteria.

Figure 14. Split of EUEL licenses and licensed paint and varnish products by awarding Competent Body as of Sept. 2023



Source: EU Ecolabel statistics – European Commission[82].

The data above shows that more than half of both the awarded licenses and the licensed products are associated with three Member States: France, Spain and Germany. The award of EU Ecolabel paints and varnishes is especially high in Greece (the 4th most popular Competent Body) if the general Member State population is also considered. Although not shown in the figure above, there were 11 Member States with zero licenses or licensed products (AT, BG, CZ, HR, HU, IE, LU, LV, MT, NO and SK).

What type of paint and varnish products are getting the EU Ecolabel? All products falling within the scope of Decision 2014/312/EU carry the same code number on the EU Ecolabel that appears on the packaging. Consequently, the official EU Ecolabel statistics do not offer any further information about which of the many different types of paint or varnish product are being ecolabelled.

Limited feedback received in the preliminary questionnaire did however reveal some insights into the types of products that were being awarded the EU Ecolabel (at least by those providing the feedback). For example, the share of indoor products was higher than outdoor products (60-80% indoor versus 20-40% outdoor). Decorative paints (wall and ceiling) were considered as the most popular product category, followed by tinting systems. The tinting system products are not generally something that consumers may be aware of, since it refers to tints used to make colour blends for predefined or custom shades on demand. Licensed products also existed for a variety of other categories covered by the EUEL criteria, for example for wood paints, woodstains, masonry coatings and floor paints and coatings.

The large number of licensed products does not necessarily mean that there are lots of different products and formulations, since the same formulation can be sold in different sizes of package, and each option is considered as an individual licensed product. Furthermore, the same formulation, but in different colours thanks

82 See: EU Ecolabel Statistics – European Commission: https://ec.europa.eu/environment/ecolabel/facts-and-figures.html

to changes in the quantities and choices of tints used, can generate hundreds of variations of the same basic formulation, and each of these would be counted as an individual licensed product too.

Why did companies apply for the EU Ecolabel? This question was asked as part of the preliminary questionnaire run by the JRC in 2023. According to respondents, their company applied for the EU Ecolabel for paints and varnishes products first to increase sales (35% of responses) and to increase visibility (30% of responses). The remaining responses added some other insights, as summarised below:

— EU Ecolabel is a well-known ecological label that they want to hold.

— It is part of their environmental policy.

— Some MS have 'ecocheques' or vouchers that can be used to buy ecological and EU ecolabelled paints are products with high prospects to be acquired and potentially increase sales.

— Given that the EU Ecolabel is a well-recognised and respected certification across the European Union, by obtaining this label, a paint company can demonstrate its commitment to protect consumers. The EU Ecolabel can be used as a powerful marketing tool. Companies can leverage the label in their marketing materials, packaging, and advertising campaigns. In some cases, the EU Ecolabel may align with or even exceed certain regulatory requirements.

— It is a certification scheme that end users recognize, trust and choose when they buy paints or varnishes. The promotion from companies like us that supported the eco label scheme played a very important role in that direction.

— To meet the market needs; leading retailers increasingly requesting products be ecolabelled, public bodies mandating ecolabelled products to be used in governmental buildings & projects. So, obtaining ecolabels has become, in some countries, a pre-requisite to do business.

— To create more visibility on the environmental & health benefits of our products, leveraging the awareness of the Ecolabel.

— EU Ecolabel label allows to have a message of great added value for the market (particularly for the perception of the brand) and to satisfy that part of end customers who are sensitive to these issues.

3.5 Innovative trends

Competition, corporate sustainability goals, environmental claims, customer demand and regulation are continual drivers of innovation in the paints and varnishes sector. This section provides insights into the product, raw material and customer service innovations that are of most relevance to decorative coatings.

— The increased focus of major paint and varnish manufacturers on environmental impacts.
— Development, due to the sustainable agenda, but also changes in the customer demands, and technological advances.
— Research and developments in new additives and formulations. For example, a paint formulated to combat air pollution has been developed. This "smog eating paint" is effective in decomposing some pollutants, yet research has revealed it also generates and releases other toxic compounds[83].

While there are some very innovative developments like AkzoNobel´s *"Evolve"*[84] matte emulsion, which contains 35% recycled paint and a 10% lower carbon footprint, the following sections aim to look at more broadly applicable areas of innovation.

3.5.1 Answers from preliminary questionnaire

Below are summarized the answers from the preliminary questionnaire about the most recent innovation/emerging products and consumer trends. Answers were given in written form.

The following trends for more sustainable product that were highlighted were:

— There is a market demand for products with ecolabels, and which comply with requirements within sustainable construction requirements.

83 See: https://www.chemistryworld.com/news/smog-eating-paint-does-more-harm-than-good/3007932.article

84 See: https://www.akzonobel.com/en/media/latest-news---media-releases-/akzonobel-launches-recycled-paint-to-help-close-loop-on-waste

— There are trends related to the green and circular transition, where consumer and businesses are seeking for products with lower carbon emissions, for reduced environmental impacts.
— There are trends coming from an increased interest in products for individuals with allergy and in general focusing on health and indoor air quality for products with lower or zero VOC/SVOC content.
— There are trends in products with smart functionality, which can be paints which e.g. are "self-cleaning", for better maintenance or "moisture resistance".

Below are more specific answers, given by individuals or few stakeholders.

— A stakeholder indicated changes in the use of biocide and preservation in paints and varnishes.
— Innovative products are functional coatings, such as solar reflective paints which are able to help reducing the energy consumption of a building.
— There is a growing interest in biobased products, for which some stakeholders question, if the environmental performance is better, seen over a whole life cycle, and a potential compromising of the performance.
— A focus on paints containing recycled raw materials.
— One respondent also pointed to the changes in classification of biocides as a driver for innovation.
— There have overall been few comments, mentioning the concern in some innovations, maybe requiring further research. As an example, two respondents alerted about regulatory changes not always leading to more sustainable options, and that some changes will compromise the performance of the product, which consumers are not ready for.

3.5.2 Low Volatile Organic Compound (VOC) content paints and varnishes

There has been a growing demand for paints and varnishes with lower VOC contents, both from consumer demand, environmental schemes (ecolabels and green building certification schemes) and from regulatory pressure. In the EU, the industry has had to comply with mandatory VOC and Semi-VOC (SVOC) limits set out in Directive 2004/42/CE[85]. These limits are already 20 years old and more stringent limits on total VOCs and SVOCs have been set out for paints and varnishes in different (but voluntary) ISO 14024 Type I ecolabels in Europe – such as the EU Ecolabel[86], the Blue Angel[87] and Nordic Swan[88].

Specific limits for individual VOC emissions have also been set out in some EU Member States based on national regulations. In the French market, a compulsory VOC labelling scheme has been set up for construction and decoration products, including paints. While no upper limits exist, it would mean that a paint product could be labelled with the worst VOC emission class of "C". Testing needs to be carried out according to an ISO 16516 chamber test, using the European Reference Room defined in EN 16516 and chamber air concentrations after 28 days need to comply with the following limits for each of the VOC classes.

Table 21. VOC limits for the French VOC label for construction and decorative products, including paints.

Parameter	CAS No	Class C (µg/m3)	Class B (µg/m3)	Class A (µg/m3)	Class A+ (µg/m3)
Total VOC		> 2000	< 2000	< 1500	< 1000
Formaldehyde	50-00-0	> 120	< 120	< 60	< 10
Acetaldehyde	75-07-0	> 400	< 400	< 300	< 200
Toluene	108-88-3	> 600	< 600	< 450	< 300

85 See: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:143:0087:0096:EN:PDF

86 See: https://www.euecolabel.eu/ ; specific coating related: https://ec.europa.eu/environment/ecolabel/documents/paints.pdf

87 https://www.blauer-engel.de/en/products; specific paint related: https://www.blauer-engel.de/en/productworld/wall-paints-indoor/binding-primer-for walls?mfilter%5B0%5D%5Btype%5D=producttypes&mfilter%5B0%5D%5Bvalue%5D=532&url=https%3A%2F%2Fwww.blauer-engel.de%2Fen%2Fproductworld%2Fwall-paints-indoor%2Fbinding-primer-for-walls

88 See: https://www.nordic-swan-ecolabel.org/; specific paints and varnish related: https://www.nordic-swan-ecolabel.org/criteria/paints-and-varnishes-096/

Parameter	CAS No	Class C (µg/m3)	Class B (µg/m3)	Class A (µg/m3)	Class A+ (µg/m3)
Tetrachloroethylene	127-18-4	> 500	< 500	< 350	< 250
Ethylbenzene	100-41-4	> 1500	< 1500	< 1000	< 750
Xylene	1330-20-7	> 400	< 400	< 300	< 200
Styrene	100-42-5	> 500	< 500	< 350	< 250
2-Butoxyethanol	111-76-2	> 2000	< 2000	< 1500	< 1000
1,2,4-Trimetylbenzene	95-63-6	> 2000	< 2000	< 1500	< 1000
1,4-Dichlorobenzene	106-46-7	> 120	< 120	< 90	< 60

Source: Décret No. 2011-321[89] and Eurofins website[90].

In Italy, a compulsory requirement for any coatings used in green public procurement for public buildings or private ones that receive government funding, is that any construction, decoration and furnishing products included in the procurement exercise must comply with the following VOC emission limits (after 28 days in an EN 16516 chamber test):

- Benzene, Trichloroethylene, DEHP, DBP: < 1 µg/m³ for each parameter
- Formaldehyde: < 60 µg/m³
- 1,4-Dichlorobenzene: < 90 µg/m³
- Acetaldehyde, Xylene: < 300 µg/m³ for each parameter
- Tetrachloroethylene, Styrene: < 350 µg/m³ for each parameter
- Toluene: < 450 µg/m³
- Ethylbenzene: < 1000 µg/m³
- TVOC, 2-Butoxyethanol: < 1500 µg/m³ for each parameter

The shift to lower VOC content coatings means the use of water-based formulations instead of organic solvent-based ones. All of the major paint and varnish manufacturers have ultra-low or zero-VOC formulations on the market for decorative paints. This can be achieved by a shift to water-based formulations or to very high solids content in solvent-borne formulations. Some examples of relevant VOC-free paints on the market today include:

- Super Hide Zero VOC (interior), Ultra Spec 500 (interior), Eco Spec (interior), Ben (interior) and Waterborne Ceiling Paint (ceiling) by Benjamin Moore[91].
- ProMar 200 (interior latex); ProMar 400 (interior latex) and ProMar (interior latex primer) by Sherwin-Williams[92].
- Various interior wall & ceiling paints[93] (matte, eggshell, chalkboard), various floor paints[94] (interior, interior anti-slip, exterior porch and floor), various exterior paints[95] (exterior vinyl siding, exterior satin wall, semi-gloss, gloss, exterior low-lustre wall) offered by ECOS.
- Milk paints offered by the Real Milk Paint Co[96].

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89 See: https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000023759679

90 See:https://www.eurofins.com/consumer-product-testing/services/certifications-international-approvals/voc/legal-requirements/

91 See: https://www.benjaminmoore.com/en-us/search?q=zero&category=product&start=1#global-content

92 See:https://www.sherwin-williams.com/SearchDisplay?storeId=10151&catalogId=11051&langId=-1&sType=SimpleSearch&resultCatEntryType=2&showResultsPage=true&searchSource=Q&beginIndex=0&pageSize=15&pageView=list&searchType=1000&searchTerm=zero%20voc&currTab=Products#facet:&productBeginIndex:0&contentBeginIndex:0&orderBy:&orderByContent:&pageView:list&minPrice:&maxPrice:&pageSize:15&

93 See: https://ecospaints.net/paints/wall-and-ceiling

94 See: https://ecospaints.net/paints/floors

95 See: https://ecospaints.net/paints/exterior-paints

96 See: https://www.realmilkpaint.com/paint/

3.5.3 Air purifying paints

The same concerns about indoor air quality that have been promoting low- and zero-VOC content interior paints has been behind a limited number of novel paint products that are marketed with claims of air purifying properties. The functionality of air purification is not well defined yet and could potentially refer to:

- reductions in indoor formaldehyde concentrations and odorous compounds via zeolites, embedded activated carbon or photocatalytically active TiO_2,
- CO_2 removal via lime carbonation,
- killing of airborne bacteria landing on surfaces due to high pH of lime,
- killing of airborne bacteria landing on surfaces due to embedded nanosilver.

Some examples of air purifying paints include *Graphenstone* by the Organic & Natural Paint Co.[97], *SuperPaint Interior Acrylic* (one formula with "air purifying technology" and one with "sanitizing" technology) by Sherwin-Williams[98], *Aircare* by Nippon Paint[99], *Respisafe* (anti-formaldehyde/VOC) and *Medguard+* (anti-viral and anti-bacterial) by Colortek[100], *Royal Atmos* by Asian Paints[101], *KNOxOUT* by Boysen[102], *Formashield* by Dow[103] and various products by ECOS[104], which also include a primer and a varnish.

The adoption of digitalization within the paint and coatings industry has accelerated since 2020. Digital technologies have been increasingly integrated into the paints and varnishes industry, enabling custom colour matching, online product selection, and virtual visualization of paint applications. Pandemic-fueled market shifts highlighted digital color management's role as an essential part of the industries competitive space. As a result, companies are rapidly embracing digital workflows to increase customer satisfaction by ensuring accurate colour matching. Digital solutions also benefit paint retailers and manufacturers by streamlining colour development, improving quality control, cutting costs and increasing sustainability[105]. Companies are leveraging digital platforms to enhance customer engagement and provide personalized solutions.

3.5.4 Biobased ingredients

Many of the major raw materials used in paints are based on organic chemicals that are derived from petrochemical sources, like resins, binders, organic solvents and many of the diverse array of additives that can be used. An article[106] published by European Coatings highlighted that there is very little knowledge about the current share of biobased formulations, and that an estimate could be around 1% by volume and 5% by sales. The same article highlighted the cross-cutting active promotion of biobased content that exists in Dutch public procurement rules and the requirement of biobased contents of at least 95% if one of the top two classes (A or A-) is to be awarded to a paint under the Swiss ecolabel Umweltetikette[107].

However, question marks remain about how the use of biobased alternative raw materials compares to the petrochemical originals from an LCA perspective. The recommendation from the Communication 'EU policy framework on biobased, biodegradable and compostable plastics'[108] suggests using the latest methodology available to demonstrate the environmental profile of the biobased raw materials to compare with non-biobased raw materials. The methodologies suggested in this Communication are the framework developed by

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97 See: https://organicnaturalpaint.co.uk/natural-paint/air-purifying-paints/

98 See: https://www.sherwin-williams.com/architects-specifiers-designers/inspiration/stir/sw-expert-how-superpaint-works

99 See: https://www.nipponpaint.com.my/products/topcoat/Odour-less-AirCare

100 See: https://www.colortek.eu/products-details/13/architectural-paints/anticarbonation

101 See: https://www.asianpaints.com/campaign/royale-atmos/index.html

102 See: https://www.myboysen.com/boysen-knoxout-air-cleaning-paint/

103 See: https://www.dow.com/pt-br/pdp.formashield-12-emulsion.237623z.html#overview

104 See:https://ecospaints.net/browse-all/air-purifying-paint

105 See:Article, Paints & Coatings Industry, 2022, https://www.pcimag.com/articles/110025-a-case-study-examining-the-benefits-of-digital-color-management-in-the-paint-industry

106 See: https://www.european-coatings.com/news/markets-companies/bio_based-coatings-overview-increasing-activities/

107 See:https://stiftungfarbe.org/

108 See:https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022DC0682

the Commission's Joint Research Centre, referred to as the 'Plastics LCA method'[109] or the Commission Recommendation of 8.12.2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials[110]. Moreover, the recent publication from the Renewable Carbon Initiative (RCI) entitled 'Non-level playing field for renewable materials vs fossil in Life-Cycle Assessments'[111] gives additional context and thus considers that the footprint of fossil feedstocks is not evaluated in a transparent way, suffering of a lack of regional differentiation which ends probably in underestimation of the actual values. This publication also highlights that biobased and/or renewable materials are more critically evaluated than fossil feedstocks. Precisely, whereas in the assessment of biobased materials biodiversity, direct and indirect land use are investigated including details such as machinery used, a similar investigation for the LCA of crude oil is not requested. All in all, this type of assessment is an especially sensitive issue if the biobased materials are derived from palm oil or palm kernel oil, whose production is associated with major biodiversity impacts and deforestation in Indonesia and Malaysia in particular[112]. Similar studies looking at the effect of shifting from petrochemical sources to oleochemical sources like palm oil for the production of surfactants in detergent products generally showed only very modest reductions in fossil resource depletion but huge increases in land use impacts[113].

3.5.5 Product Carbon Footprint or LCA

The Together-for-Sustainability (TfS) initiative recently published a report called 'The Product Carbon Footprint Guideline for the Chemical Industry'[114] which intends to provide a series of certain guidelines to establish the Product Carbon Footprint (PCF) of chemical substances and/or products (as the previously reported EU recommendation on Environmental Footprint methods[115]). The newer guidelines differ from the EU Commission recommendation in several points such as: (a) inclusion of biogenic carbon removals; (b) specific issues and requirements in the calculation of a product carbon footprint (PCF) are more extensively addressed (namely, functional unit, guidance to categorize, evaluate and use data sources, rules for treatment of biomass, biomass balanced products, recycled materials etc) and (c) while a cradle-to-grave approach is selected in the EU recommendation, a cradle-to-gate is used in the TfS guideline (aiming to differentiate the impacts from the manufacturing and consumer stages). Besides, the TfS guideline proposes a specific reporting scheme with five separate emission values which are then combined to a PCF-value for communication purposes. The five (5) specific PCF-values to be reported are: (1) the fossil CO_2eq -emissions (net result of fossil emissions and removals; (2) biogenic CO_2eq -emissions (only GHG emissions other than CO_2 – excluding biogenic CO_2); (3) land use and direct land use change CO_2eq –emissions; (4) biogenic removals (biogenic CO_2 contained in the product); and (5) aircraft CO_2eq -emissions. This could be useful for a potential criterion on carbon footprint of indoor and outdoor paints and vanishes products.

[109] See: available at https://publications.jrc.ec.europa.eu/repository/handle/JRC125046

[110] See: (available at https://research-and-innovation.ec.europa.eu/system/files/2022-12/Commission%20recommendation%20-%20establishing%20a%0European%20assessment%20framework%20for%20safe%20and%20sustainable%20by%20design.PDF)

[111] "Non-level playing field for renewable materials vs. fossil in Life Cycle Assessments – Critical aspects of the JRC Plastics LCA Methodology and its policy implications" (January 2024) https://renewable-carbon.eu/publications/product/rci-non-level-playing-field-for-renewable-materials-vs-fossil-in-lcas/

[112] Jong, H. N., 2023, Palm oil giants Indonesia, Malaysia start talks with EU over deforestation rule, Mongabay, https://news.mongabay.com/2023/09/palm-oil-giants-indonesia-malaysia-start-talks-with-eu-over-deforestation-rule/

[113] Arendorf et al., 2014a, 2014b, 2014c and 2014d.

[114] The Product Carbon Footprint Guideline for the Chemical Industry https://www.tfs-initiative.com/app/uploads/2024/03/TfS_PCF_guidelines_2024_EN_pages-low.pdf

[115] Commission Recommendation (EU) 2021/2279 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021H2279

Table 22. Effect of changing from petrochemical to oleochemical sources on results of selected LCA impact categories for the cradle-to-grave life cycle of different detergent products.

Impact category *	Laundry Detergent		Dishwasher Detergent		Hand Dishwashing Detergent		Hard Surface Cleaner		
	Petro-	Oleo-	Petro-	Oleo-	Petro-	Oleo-	Petro-	Oleo-CO*	Oleo-PKO*
POF	100%	100.0%	100%	100.0%	100%	101.3%	100%	110.3%	96.6%
PMF	100%	100.9%	100%	100.0%	100%	100.0%	100%	115.4%	100.0%
TEcoT	100%	157.0%	100%	149.8%	100%	1850.6%	100%	8750.0%	10000.0%
ALO	100%	111.7%	100%	102.8%	100%	284.7%	100%	456.3%	1437.5%
NLT	100%	99.9%	100%	100.0%	100%	665.8%	100%	110.0%	3100.0%
MD	100%	100.0%	100%	100.0%	100%	103.6%	100%	121.7%	117.4%
FD	100%	98.0%	100%	100.0%	100%	95.9%	100%	94.7%	94.7%

*POF stands for Photochemical Oxidant Formation; PMF stands for Particulate Matter Formation; TEcoT stands for Terrestrial EcoToxicty; ALO stands for Agricultural Land Occupation; NLT stands for Natural Land Transformation; MD stands for Metal Depletion; FD stands for Fossil Depletion; CO stands for Coconut Oil and PKO stands for Palm Kernel Oil.

Source: Adapted from Arendorf 2014a, 2014b, 2014c and 2014d.

A similar sensitivity analysis would need to be carried out with paints and varnishes before any conclusions could be made regarding the credibility of pushing biobased content claims as part of ecofriendly products. Other biobased sources with lower environmental footprints than palm oil could be interesting, especially waste products and by-products, although if being used in water-based products, care with potential microbial contamination and subsequent spoilage would need to be accounted for.

3.5.6 Biocide-free paints

The most relevant paint and varnish products for the EU Ecolabel are water-based, normally close to neutral pH, and generally contain high quantities of organic substances that could be a food source for microbes already present in the mixture. Added to the fact that most current business models count on a 2-year shelf life for paint products, the need for in-can preservation is well justified.

There are a relatively small number of biocidal active substances that are suitable for use as in-can preservatives or dry-film preservatives. The industry has moved away from the family of formaldehyde-releasing preservatives due to formaldehyde being classified as a suspected carcinogen. The isothiazoline family of substances has a long history of use in paints and varnishes but have been recently reclassified with much stricter threshold concentrations relating to skin sensitization. The result of this is that less and less isothiazoline compounds can be used unless the manufacturer is okay with their coating products being marketed as skin sensitizing on the packaging. Research into new and less hazardous biocides is not likely to deliver major breakthroughs in the next few years, although the promise of certain alternatives like kimchi fermentation peptides or antimicrobial polymers has been mentioned in this article[116] by the ACA (American Coatings Association).

Ways to minimize or altogether avoid the need for biocides in paint and varnish products can include:

- Business models that require reduced shelf-life times for products (e.g. 4 months compared to 2 years).
- Refrigerated storage of biocide-free products.
- Improved plant hygiene to reduce microbial contamination during manufacturing.
- Reducing or avoiding untreated or wet raw materials.
- Use of inorganic formulations (no organic substrate for microbes to feed on).
- Use of high pH formulations.
- Airspace in closed containers being filled with nitrogen instead of air during packing at factory.
- Reduction of water activity in formulations.
- Hydrophobic surface to reduce or avoid need for dry-film preservation.

[116] See:https://www.paint.org/coatingstech-magazine/articles/challenging-preservation-options-towards-biocide-free-waterborne-coatings-via-innovative-binders-and-additives/

— The use of anti-septic packaging.

Biocide-free paints are slowly starting to enter the market. One interesting approach is interior wall paints in powder form, with water only being added immediately prior to application – for example see the NEXIVA product line from Wacker Chemie AG[117]. This has the added advantage of reduced waste, since users can mix up the exact quantities they need instead of buying from the nearest bucket.

The best-known biocide-free paints are silicate mineral wall paints with a pH of 10-11. While these products are very popular in the German DIY sector, they are very rare in the rest of Europe. According to Lemain & Mensink (2021)[118], the popularity of biocide-free paints in Germany is due to consumer demand. The same study estimated that the price premium for biocide-free paints can be up to 30%, but that customers make decisions mainly (95%) based on price. However, it should be noted that silicate paints have some technical limitations, such as being too porous and thus offering poor wet scrub resistance, and this limits their durability and potential range of applications. Some of these technical limitations may however be addressed by innovation in the additives sector, such as the two stabilizers developed by Clariant[119] in 2017.

Due to the adverse effects of biocides on both human health and the environment, there has been a growing demand for biocide-free paints. In the period 2023-2030, the market for biocide-free paints is projected to grow 8.6%[120].

3.5.7 Strengths, Weaknesses, Opportunities and Threats (SWOT) of the market

This section provides an overview of the strengths, weaknesses, opportunities and threats of European paint and varnish manufacturers. The SWOT is summarized in Table 23, with further elaborations below the table. The SWOT is made for European paint and varnish manufacturers, from a global perspective.

Table 23. Overview of the main points from the SWOT analysis.

SWOT Analysis	
Strengths	Weaknesses
Innovation and quality Strong brand reputation Focus on sustainability Well-developed supply chains Increasing prices	Regulative pressure Higher raw material prices Higher production prices Competitive market Impacts through economic uncertainties
Opportunities	Threats
Benefit from growth in construction sector Benefits from emerging markets Demand for products with lowered environmental impacts Digitalization	Competitive market Economic uncertainties Changing consumer preferences Stricter regulations

Source: Adapted from MBA simple words SWOT analysis.

117 See: https://www.wacker.com/cms/en-us/products/brands/nexiva/nexiva.html

118 Lemain S. and Mensink B., 2021. "In-can preservatives in the paint industry. How to stimulate alternatives to biocides." Report BH7424RP001F01 for the Dutch Ministry of Infrastructure & Water Management.

119 See: https://www.coatingsworld.com/contents/view_breaking-news/2017-03-30/clariant-pioneers-easy-application-for-biocide-free-mineral-paints

120 See: Global Biocide-free Coatings Market is projected to reach the value of $17.80 Billion by 2030, https://www.openpr.com/news/3147593/global-biocide-free-coatings-market-is-projected-to-reach

3.5.7.1 Strengths

The paint industry offers a wide array of products, including decorative paints, automotive coatings, and industrial coatings like protective coatings. This diversity enables companies to cater to various customer segments, including potential niche markets. The broad product range reflects the diverse needs and consumer demands[121].

Decorative paints play a crucial role in both aesthetics and surface protection, offering stability and growth opportunities within the industry. By providing a selection of finishes, such as matte, satin, and gloss, companies can offer consumers more choices to achieve their desired home aesthetics.

The extensive product portfolio, coupled with increasing market regulations, necessitates significant investment in research and development. This investment is crucial for developing innovative products, enhancing formulations, and introducing eco-friendly and sustainable options, which are becoming increasingly important to environmentally conscious consumers. Additionally, research and development efforts are directed towards improving product quality and durability, ensuring long-lasting results for customers[122].

Innovation and quality: European manufacturers generally produce high-quality products, and are leading innovation, leveraging advanced technologies and formulations to meet the market requirements of both performance, aesthetics, and environment and health requirements.

Strong brand reputation: The above innovation and quality also gives European brands a reputation for high quality products and reliability and accountability in global markets, as well as high consumer trust.

Focus on sustainability: European manufactures generally prioritise sustainability and health aspects, offering formulations with low VOC content and environmentally responsible manufacturing processes, aligning with the generally increasing consumer demand for green products.

Well-developed supply chains: The accessibility of key raw materials from reliable suppliers, and access to well-developed infrastructure, ensures reliable and efficient supply chains for production in Europe.

Increasing prices: From the assessment in chapter 4, it is seen that on the export market, the value of exports has gradually increased, while the quantity of exports has not to the same degree, meaning that the paint products are sold for higher prices, generating increased revenue for manufacturers.

3.5.7.2 Weaknesses

Regulative pressure: As highlighted earlier, the paint industry is increasingly challenged by stricter regulations aimed at reducing environmental impact, particularly concerning volatile organic compounds (VOCs) and hazardous waste. Companies that do not adapt to these evolving regulations and shifts in consumer preferences risk experiencing decreased demand and a loss of market share.

Higher raw material costs: Given that paints and varnishes are composed of a variety of raw materials, the industry is particularly sensitive to the costs of key components like pigments and resins. Fluctuations in these costs can impact profit margins and pose challenges for companies trying to maintain stable prices or optimize expenses, thereby intensifying competition.

Competitive market: The competitive landscape is further exacerbated by numerous brands and manufacturers vying for market share, sometimes leading to price wars, and diminishing profitability. This competitive pressure is also evidenced by the frequent acquisitions within the industry, as discussed in section 1.3.1.

Higher production costs: Due to the higher costs for regulatory expenses and labour costs in Europe, European producers may face higher production costs compared to competitors in regions with lower labour and regulatory expenses. This can also impact pricing competitiveness in global markets, and especially restrict access to emerging markets, where price is weighed over quality.

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[121] See: MBA Simple words, SWOT Analysis of paint Industry, 2023, https://mbainsimplewords.com/swot-analysis-of-paint-industry/

[122] See: MBA Simple words, SWOT Analysis of paint Industry, 2023, https://mbainsimplewords.com/swot-analysis-of-paint-industry/

Impacts through economic uncertainties: The demand for paints is closely tied to economic conditions and the level of construction activity. In times of economic downturns or reduced construction activity, paint demand may fall, adversely affecting the revenues and profitability of paint companies.

Purchases of paints and coatings are often discretionary and influenced by consumer and business spending trends. Economic uncertainties can lead to cutbacks in spending on non-essential items, including paints and varnishes.

A potential vulnerability in the paint industry's supply chain is the management of raw material procurement and distribution. Inefficiencies or disruptions in this area can lead to delays or shortages, affecting production schedules.

3.5.7.3 Opportunities

Benefit from growth in construction sector: The paint industry stands to gain from expansion in the construction and infrastructure sectors, which necessitate paints for both functional and aesthetic purposes.

Benefits from emerging markets: Especially in emerging markets, significant growth is anticipated. Regions such as Asia-Pacific and Latin America present substantial opportunities for the paint industry, driven by urbanization, increasing wealth, rising per capita incomes, and heightened construction activities. If the European manufacturers can find right price points, this is a growth opportunity.

Demand for products with lowered environmental impacts: Growth opportunities also emerge from the escalating demand for eco-friendly and sustainable paint products. This demand is fuelled by consumer preferences, eco-labels, and regulations that advocate for environmental sustainability. The environmental challenges we face are creating opportunities for increased sustainability awareness, and the push for greener products opens new avenues for paint companies to innovate in this area. The shift towards eco-friendly and sustainable solutions not only allows for market expansion but also enables companies to capture new segments and customer bases.

Digitalization: Moreover, the advent of digitalization and the proliferation of online platforms and e-commerce channels offer paint companies an additional avenue for sales, enabling them to reach a wider audience and simplify the buying process. The digital platforms also help illustrate paint in the customers own rooms using AR (Augmented Reality), or similar tools for optimizing purchase experience.

3.5.7.4 Threats

A primary threat within the paint and varnish industry is market competition, predominantly driven by price due to numerous producers offering similar products. This competition is further intensified by shifting consumer preferences, which compel companies to allocate resources to research and development.

Competitive market: The industry is marked by fierce competition, with established brands and new entrants alike striving for a larger share of the market. To maintain a competitive edge, continuous innovation and price competitiveness are essential.

Economic uncertainties: Economic recessions or downturns also pose significant threats, as they may lead to reduced spending on paints and varnishes by both consumers and businesses, thereby affecting the industry's revenue. Furthermore, the volatility in raw material costs, often exacerbated by economic downturns, can strain the profit margins of companies within the sector.

Changing consumer preferences: Another looming threat is the potential replacement of paints and varnishes with alternative materials, such as wallpaper or other wall coverings, offering different aesthetic or functional benefits.

Stricter regulations: The industry faces challenges from stricter environmental regulations and heightened scrutiny concerning the use of VOCs (Volatile Organic Compounds) and hazardous materials, necessitating further investment in development to comply with these standards.

3.6 Conclusion

Market penetration of EUEL

The 2009 EU Ecolabel criteria initially led to approximately 225 licenses covering around 7500 products, but with the full implementation of the 2014 criteria, there was a significant decrease in licenses and licensed products by around 73%. However, since then, both the number of licenses and products have steadily increased again, with the current criteria accommodating a larger number of producers, resulting in each EU Ecolabel license being associated with more licensed products. However, there was a notable drop in licensed products in 2020 by around 33%, attributed to the need for formulation adjustments following CLP reclassifications of preservatives.

Data shows that more than half of both the awarded EU licenses and EU licensed products are associated with three Member States: France, Spain and Germany. The awarding of the EU Ecolabel to paints and varnishes is especially high in Greece (the 4th most popular Competent Body) if the general Member State population is considered. There are 11 Member States with zero licenses or licensed products (AT, BG, CZ, HR, HU, IE, LU, LV, MT, NO and SK).

Feedback from the preliminary questionnaire indicated that indoor products received a higher proportion of EU Ecolabel awards compared to outdoor products, with decorative paints being the most popular category followed by tinting systems.

In a preliminary questionnaire conducted by the Joint Research Centre (JRC) in 2023, the primary motivation for companies applying the EU Ecolabel was to increase sales, accounting for 35% of the responses. This was closely followed by the desire for increased visibility, which represented 30% of the feedback. Additional reasons cited for applying included alignment with their environmental policies, incentives such as vouchers provided by member states for EU Ecolabelled products, and the recognition of the EU Ecolabel as a trustworthy certification scheme.

Production value chain

The production value chain in the coatings industry progresses from raw materials to ingredients for coating formulations, then to mixing and packaging at production sites before shipment to customers.

Three main sales relationships are:

- Industrial customers using coatings in their production lines,
- Wholesalers focussing on large quantity sales,
- Large retailers or specialist paint shops selling to DIY and professional customers, often offering custom colour options.

Paint and varnish products are mixtures of raw materials blended under controlled conditions by manufacturers. These raw materials constitute 40-60% of the production costs for paint and varnish.

Raw materials in coatings can overall be segregated into resins, pigments and fillers, solvents, and additives.

Production, sales, prices and imports/exports

Between 2014 and 2022, there was a slight decrease (-1.4%) in the total production of acrylic and vinyl polymer paints at the EU level, with major Member States like Germany, France, Italy, Poland, and Spain dominating production, accounting for about 75% in 2014 and 73% in 2022 of the EU27 production. However, this stability masks notable decreases in Germany, France, and Poland, alongside increases in Italy and Spain, which collectively contributed around 230 million kg to production. Additionally, noteworthy relative increases occurred in Latvia (almost 5-fold), Slovenia (more than 2-fold), and Croatia (almost 2-fold) during this period.

Between 2014 and 2022, the total production quantities of other water-based paints at the EU level decreased slightly (-0.9%), amounting to about one-fourth of the acrylic or vinyl polymer category. Major producing Member States like France and Poland had, compared to acrylic and vinyl polymer paints, more modest shares of production (3.3% and 6.0% in 2022, respectively), while approximately 74% of EU production was concentrated in Germany, Spain, Italy, and Romania. Significant relative increases in production were observed in Greece (almost 6-fold), Poland (almost 3-fold), Denmark (more than 2-fold), and Lithuania (almost 2-fold), with Croatia experiencing a notable decrease in the "other" category, potentially due to data correction.

The data reveal that the water-based formulations are significantly cheaper (around 33% to 50% cheaper) on a per kg basis than the organic solvent-based formulations.

Analysing the unit prices shows the domestically produced and consumed products are generally cheaper than both imported and exported products. From the fact that unit prices are higher for both imports and exports, and for both types of water-based paint, it can be implied that transport and storage costs are significant contributors to unit cost.

Key actors and brands

Key stakeholders in the global paints and varnishes market include raw material suppliers, distributors, regulatory bodies, commercial research and development institutions, importers/exporters, government organizations, trade associations, industry bodies, and end-use industries.

The demand for coatings by volume in 2022 was dominated by the Asia Pacific region (45%), followed by Europe (23%), North America (19%), Latin America (7%), and the Middle East & Africa (6%).

Sales data indicates that PPG and Sherwin-Williams are the top two leading companies in the coatings industry, followed by AkzoNobel, Nippon Paint, and RPM. The top 5 European paints and coatings companies in 2023 are AkzoNobel (Netherlands), BASF (Germany), Jotun (Norway), Hempel (Denmark) and DAW (Germany).

4 Task 3: Technical Analysis

The aim of this chapter is to support the EU Ecolabel revision process for indoor and outdoor paints and varnishes, by providing technical information on these products related to manufacturing processes, and environmental and health issues.

The analysis describes the paint and varnish manufacturing and role of the different raw materials in the product. Then it addresses the environmental impacts through 1) an LCA (Life Cycle Assessment) literature review, and then by performing a screening LCA study, according to the existing PEFCR for decorative paints.

The LCA results are not directly relatable to health issues, and the report therefore looks into the presence in paints and varnishes of chemicals of potential concern in terms of environmental and human hazard, based on the CEPE Ingredients list[123] and the ECHA database. A special focus is put on preservatives, titanium dioxide and VOCs (Volatile Organic Compounds). Finally, some indicative improvement potentials and best practices are listed.

4.1 Technical analysis of manufacturing technologies

This section describes the essential stages of paint and varnish manufacturing, providing an overview of the processes involved. The manufacturing of paints and varnishes is a complex process that involves several steps to ensure the final product meets the required quality and performance standards. The manufacturing process for both paints and varnishes begins with raw material preparation, including grinding of dispersing pigments (in the case of opaque products) and other solids to a fine powder. These powdered materials are then mixed with water or another solvent.

4.1.1 Raw materials selection and preparation

The correct selection and preparation of raw materials are fundamental to the paint and varnish manufacturing process. This step involves choosing the appropriate pigments, solvents, resins, and additives. The choice of these materials significantly impacts the final product's colour, consistency, drying time, and overall performance.

Pigment Selection: Pigments are chosen based on the desired colour and opacity. Natural pigments come from minerals or plants, while synthetic pigments are chemically engineered for brightness and durability. The particle size and shape of pigment particles are also considered, as they affect the colour strength and the paint's overall appearance. The prevailing pigment is Titanium Dioxide (TiO_2), which is used in most white and coloured paints due to its high opacity and sheen. Although TiO2 is an expensive raw material, the main alternatives, such as Zinc Sulphide (ZnS), Zirconium Dioxide (ZrO_2) and Barium Sulphate ($BaSO_4$) simply do not have light scattering coefficients or refractive indices that allow them to work as well as TiO_2 on a 1-to-1 substitution basis[124]. A more common approach is to use pigment extenders, which are cheaper white inorganic minerals that allow lower amounts of TiO_2 to be used without compromising properties of the white paint product. Complete replacement of TiO_2 without compromising the technical properties of the paint product and dry-film has proven to be a major challenge for the industry.

Solvent Selection: Solvents play a crucial role in paint formulation. For water-based paints, water acts as the primary solvent, offering environmental benefits due to low VOC emissions. Solvent-based paints, on the other hand, require organic solvents like mineral spirits or turpentine, which dissolve the resins and help the paint to form a uniform layer upon application. The choice of solvent impacts the paint's drying time and VOC levels. According to preliminary data gathered from Competent Bodies, all Ecolabelled paints are water-based.

Resin/Binder Selection: Resins are the binding agents that hold the pigment to the surface after the paint dries. The selection of resins is influenced by the desired finish (matte, glossy, etc.), durability, and resistance to environmental factors. Options include acrylic, epoxy, alkyd, and polyurethane, each offering distinct advantages in terms of film formation and adhesion. While these are the most common binder types, other options include oils, waterborne emulsions, and even natural binders like proteins or starches.

[123] See:https://lcdn-cepe.org/processList.xhtml?stock=EF_3_1_logical_datastock

[124] Adapted from information presented by Flapper J., and de Jong, H., 2018. A theoretical study into the hiding power of white TiO2-free coatings. Presentation at the EC TiO2 Forum in Berlin, 10-1-2018. Presentation available online here: https://www.european-coatings.com/news/raw-materials/titanium-dioxide-ruling-opacity-out-of-existence/

Additives Incorporation: Additives are used to enhance specific properties of the paint or varnish. Common additives include:

- Extenders and fillers to reduce the need for other more expensive raw materials.
- Driers to accelerate drying time.
- Plasticizers to improve flexibility and prevent cracking.
- UV Stabilizers to protect against sun damage.
- Anti-foaming Agents to reduce bubbles during application.
- Preservatives to extend shelf life by preventing microbial growth.

Typically, a paint/varnish consists of 10-15 different ingredients. Once selected, the raw materials undergo various preparation processes. Pigments are ground to a fine powder to ensure even dispersion. The gloss is determined by how fine the pigments are ground, which is influenced by the time of grinding and on the machine. For very high-quality paint, pigments may even be passes through a pearl mill (a rotating drum with a lot of glass spheres), however this is seldom used for normal house paints.

Resins may be modified or mixed with other components to achieve the desired viscosity and binding properties. Solvents and additives are measured and prepared for integration into the paint or varnish formula. Some ingredients might need to be heated to activate. E.g. agents to make viscosity lower during paint, but higher when not painting.

Quality Control of Raw Materials: Before entering the production process, all raw materials are subjected to quality control tests to ensure they meet the specified standards. This includes checking for purity, colour strength, consistency, and compatibility with other components.

4.1.2 Binder/resin Production

Binders are crucial for paint's adhesion and consistency. The choice of resin and the reaction conditions are vital. Different binders require varied production steps, primarily due to the chemical reactions involved in the mixtures.

Binder production can involve various stages depending on the specific type of binder and desired properties. Some binders require initial reactions followed by after-treatment, while others might have more complex multi-step processes. These reaction processes and after-treatments requires high temperatures (100-200 C), and reaction times of 2-8 hours. These conditions are necessary to facilitate the chemical reactions that create the unique properties of binders.

4.1.3 Paint Production (Water and Solvent-Based)

In the production processes of water-based and solvent-based paints, there are key differences in energy use, thermal management, and waste handling, despite their similar initial steps.

A first step for paint production, after the raw material preparation, is often to make a “pre mixture”, which is in essence a white base-paint, sometimes with a thicker consistency, which can be made in large batches. This pre-mixture, which acts as a uniform foundation, can then be stored and eventually further processed into paint.

Water-Based Paint Production Process

The production of water-based paints involves blending a water-based pre-mixture with additional components such as coloured pigments, certain additives and thinners (water) to achieve the final paint properties. This process is pivotal for ensuring the paint's application properties and durability. The pre-mixture stage in water-based paint production does not necessitate heating or cooling. Energy consumption in paint production is primarily associated with mechanical processes like pumping the mixture through production lines, stirring for homogeneity, and draining into containers. The rinsing phase employs water, leading to the generation of wastewater.

Solvent-Based Paint Production Process

Solvent-based paint production follows a similar initial pathway, with the blending of a pre-mixture with coloured pigments, additives and thinners (solvent) to finalize the paint's characteristics. However, this process is distinguished by the exothermic reactions during mixing, necessitating cooling systems to regulate temperature, which increases energy consumption. The use of organic solvents introduces the need for solvent recovery systems to handle residue solvent waste, typically requiring incineration or special treatment. Energy demands extend beyond mechanical processes to include cooling and managing VOC emissions.

Similarities and differences

Both water-based and solvent-based paint productions start with the blending of pre-mixtures with key components to define paint properties. The primary difference lies in the thermal management required in solvent-based paint production due to exothermic reactions, absent in water-based paint production, leading to higher energy consumption in solvent-based processes. Additionally, solvent-based paint production generates solvent waste, contrasting with the wastewater produced in water-based paint production, each necessitating different waste management strategies.

The most challenging when producing paints (and pigmented varnishes), is to get the very small pigments separated from each other in the grinding and mixing processes. This is usually achieved with a high-speed mixer with high sheer force in a quite viscous liquid (e.g. the pre-mixture) to generate enough force. This is necessary for homogenous mixing, as the very small particles in the pigment with have a high surface energy and will therefore stick together in agglomerates in the paints. If good separation is not achieved it yields a rough, uneven surface of the dried paint.

4.1.4 Varnish Production

Varnish production is distinct from paint production, mainly due to the chemical composition and the desired finish of the final product. The process involves selecting the appropriate type of resin and combining it with hardeners and sometimes solvents or additives, under controlled conditions, often involving heat to facilitate the necessary reactions. The choice of resin, hardener, solvents or additives, and reaction conditions significantly influences the varnish's final properties, such as clarity, durability, and resistance to environmental factors.

4.1.5 Quality Control and Testing

Quality control and testing are integral to the production process, ensuring that the paints and varnishes meet the required standards and regulations. This involves both physical and chemical testing of the products to assess properties like viscosity, colour accuracy, adhesion, and long-term durability. Compliance with safety and environmental standards is also verified during this stage. Some of the characteristics that are tested for the paints are:

Physical testing:

- Viscosity: Viscometers ensure proper application consistency and flow.
- Colour Accuracy: Spectrophotometers verify adherence to specified colour standards and batch consistency.
- Adhesion: Pull-off tests assess the paint's or varnish's ability to adhere to various surfaces.
- Drying Time: Dedicated recorders confirm adherence to drying time specifications.

Chemical Testing:

- Solids Content: Gravimetric analysis ensures proper solvent/water content, meeting regulatory requirements.
- Volatile Organic Compounds (VOCs): Measurements guarantee compliance with environmental regulations and consumer safety standards.
- Weathering Resistance: Accelerated weathering tests simulate real-world conditions to evaluate colourfastness, gloss retention, and overall durability.

4.2 Literature review

Life Cycle Assessment (LCA) is a conventional tool employed for quantifying the environmental impacts associated with a product or system. The methodology is outlined in the ISO EN 14044 standard. LCA proves to be a valuable instrument for assessing the environmental impact of paints and varnishes. The diverse compositions of paints have varying effects on both the environment and human health. Therefore, it is essential to consider the lifespan of these products in order to comprehensively evaluate their environmental impacts.

The products to be analysed in LCA studies within the paint and varnishes group, are indoor and outdoor paint, and varnishes. For the literature review were selected the Product Environmental Footprint Category Rules – Decorative Paints (PEFCR), 16 studies and 13 Environmental Product Declarations (EPDs) from three different

EPD library (International EPD library, EPD Danmark and EPG Norge) were also analysed, where 11 were concerning paints (8 for indoor paint[125], 2 for outdoor paint[126] and 1 for both[127]) and 2 for varnishes[128].

4.2.1 Methodology

Potentially relevant LCA literature was identified by the following steps:

- Keyword search for "LCA paint", "LCA varnishes", "LCA paint and varnishes", "LCA binders", "LCA resin" in the ScienceDirect, Google Scholar Library and Scopus websites.
- A review of the draft PEFCR for Decorative Paints.
- Searches for Environmental Product Declarations (EPDs) for paint and varnishes products.

Initially, studies undergo screening, primarily focusing on the relevance of their abstracts and conclusions. If a study demonstrates relevance to the analysed topic, it undergoes a secondary screening based on three criteria: (i) scope, (ii) impact assessment categories, and (iii) study outcomes. Articles or reports that meet these screening criteria proceed to a more in-depth analysis, as outlined in the able below.

4.2.2 Overview of screening results

Out of the 16 selected studies, six proved to be pertinent and were subsequently subjected to in-depth analysis, as presented in section 3.1. These studies are listed in Table 24. Furthermore, information from the previously mentioned EPDs was collected to improve understanding of the production and end-of-life phases of paint and varnishes, contributing to the definition of the LCA system boundaries.

The literature review showed that even though paint and varnishes are known to have both environmental and human health impacts, this concern is not adequately reflected in Life Cycle Assessment (LCA) analyses. Among the 16 previously selected studies, only six studies directly examined the impacts of paints and varnishes. From the discarded studies, five of them analysed building parts with paint, another three focused on tools and test methods for analysing VOC emissions, and two included the impact of wallpaper and adhesives. The limited representation of these impacts in the identified studies suggests a gap between the recognized concerns about paint and varnishes and their integration into LCA research.

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125 See: Smaltoplast paint, Flügger Performance 5, Flügger Performance 10, Dyrup professional, Smaltolux Hydro, Fenomastic Wonderwall Lux, Sigma Wall paints, Isomat Interior matt paint

126 See: Jotashied Decor traditional Tex, Dyrup Acryl mellemmalling

127 See: Paintlac

128 See: Pinturas Macy, Juno varnishes

Table 24. Overview of the selected LCA literature.

Author and year	Scope	Functional unit	Method and impact categories	Life cycle stages covered
NEUWIRTH, Josefin, et al. A ProScale case study on indoor wall paint. 2022.	The study aimed at investigating the direct human toxicity potential, for both inhalation and dermal, using ProScale for one indoor wood paint.	Protect and decorate 1 m^2 of substrate for 50 years at a specified quality level (PEFCR Paints). The reference flow was 1.409 kg/m2 specified in the PEFCR for Paints.	ProScale method to assess toxicity potentials and PEFCR – Product Environmental Footprint Category Rules (PEFCR) – Decorative Paints. (2018). v 1.0.	Raw material acquisition and pre-processing, manufacturing, distribution stage, use stage
PAIANO, Annarita, et al. Sustainable options for paints through a life cycle assessment method. Journal of Cleaner Production, 2021, 295: 126464.	This paper provides a twofold analysis: first, a comparison of two paints, characterised by different chemical compositions, has been carried out according to the current production cycle (baseline scenario); second, for each product, two additional and alternative scenarios have been hypothesised.	The functional unit (FU) was 1 kg of paint produced. The useful life of paints is identified as 50 years, which corresponds to the guaranteed duration of the product.	Based on cradle to gate' methodology. The reference Product Category Rules (PCR) for this study was the PCR ICMQ-001/15 rev.2.1 'Construction products and construction services' and the reference Central Product Classification (CPC) codes are 35110 (group 351 e paints and varnishes and related products)	Raw material acquisition and pre-processing, manufacturing, distribution stage
PAIANO, Annarita, et al. An environmental life cycle assessment of paints and varnishes in the Italian production process. XIV Convegno della rete Italiana LCA IX Convegno dell'Associazione Rete Italiana LCA, 2020, 165.	The LCA was carried out for seven products manufactured by an Italian producer company, thus these products were grouped into two categories according to their composition. The result compares the environmental impact from the products.	1 kg of paint/varnish produced with a useful life of varnishes/paints is identified in 50 years	CML baseline 2001 impact assessment and a midpoint approach including: ADPF, ADPE, AP, EP, GWP, ODP and POCP	Raw material acquisition and pre-processing, manufacturing, distribution stage
Ganesh Nayak and Vinayak Kumar (Jotun Abu Dhabi L.L.C.) – Jotun Paints. 2008	The scope of this life cycle analysis is from cradle to grave and measures the climate change impact of the five paints manufactured by Jotun Paints, Abu Dhabi in the calendar year 2007.	1L of paint for 10 years	The methodologies used for analysis are IPCC (2007) Global Warming Potential (GWP) emissions factors for a 100-year timescale and Eco-indicator 99 'Ecopoints'.	Raw material acquisition and pre-processing, manufacturing, distribution stage, use stage, End-of-life

YACOUT, Dalia; EL-ZAHHAR, Mohamed Ahmed. Environmental impact assessment of paints production in Egypt. In: Proceedings—4th international conference of biotechnology, environment and engineering sciences ICBE. 2018. p. 60-65.	The study investigates the environmental impact of paint production in Egypt, particularly focusing on "White Alkyd Enamel Paint	1000 kg Alkyd Enamel paint production	Eco-Indicator 99 and the following impact categories were considered: GWP, AP, EP, CP, ETP, RIFP, ROFP, RP, OLD, MD, land use (LU) and FFD	Raw material acquisition and pre-processing, manufacturing, distribution stage
Product Environmental Footprint Category Rules – Decorative Paints (PEFCR). 2018	The chosen representative products are based on the averages of real company formulations covering many relevant variations in paint: white or coloured paint; matt or glossy paint; solvent borne or waterborne paint.	1 m^2 of substrate for 50 years at a specified quality level (minimum 98% opacity)	The PEFCR includes the cradle to grave environmental impacts of the life cycle of decorative paints. It encompasses all the phases according to the EN15978	Raw material acquisition and pre-processing, manufacturing, distribution stage, use stage, End-of-life

Source. Own elaboration based on the literature review.

NEUWIRTH, Josefin, et al (2022) conducted a study on the application of the ProScale method in a case study focusing on indoor wall paint. ProScale assesses hazard and direct exposure potentials from chemicals along their life cycle. It can be integrated in LCA to compare human toxicity potentials of alternatives. This choice was motivated by the EU commission's inclusion of paint in its Product Environmental Footprint (PEF) pilot. The study's objective was to evaluate the direct human toxicity potential of indoor wall paint, specifically addressing inhalation and dermal exposure. Employing an attributional LCA approach, the functional unit was defined as protecting and decorating 1 m^2 of substrate for 50 years. While showcasing ProScale's relevance in a PEF context, the study acknowledges the necessity for further work, particularly in incorporating all life cycle stages of indoor wall paint. Notably, the assessment highlights that the application phase significantly contributes to the ProScale score. The study underscores the conceptual nature of the results, emphasizing that changes in the classification and labelling of titanium dioxide were not considered. As such, the outcomes should not be utilized as decision support too.

PAIANO, Annarita, et al. (2021) performed an LCA to compare two paints with different chemical compositions in their current production cycle (baseline scenario). In addition, two alternative scenarios were examined for each product, involving the incorporation of waste paint with virgin paint and a high rate of recycled packaging materials. The analysis aimed to evaluate environmental impacts, identify measures for impact reduction, and select the optimal scenario based on a circular economy approach. Additionally, the study identified the best scenario, underlining the potential circularity achieved through the collection and recycling of waste paints, previously incinerated or landfilled, in this environmentally impactful sector. The study also advocated for further research to explore innovative and natural materials as replacements for specific elements in paints, contributing to a more sustainable future.

PAIANO, Annarita, et al. (2020) investigated the environmental performance of paints and varnishes produced by an Italian chemical company using the LCA methodology. The goal was to identify main impacts and feasible measures for impact reduction. Seven products were categorized into two groups based on composition, and the average values for each category were calculated. Results indicate that module A1, influenced by silicone, chromium oxide, carboxymethyl, and resins, has the highest impact, while in module A3, polypropylene for packaging manufacturing contributes significantly. The study underscores the significance of ongoing and detailed research in the paints and varnishes sector, advocating for the use of LCA methodologies and benchmarking to identify and address environmental issues. The analysis offers the company insights into feasible measures to reduce negative externalities and supports planning activities for new business opportunities.

Ganesh Nayak and Vinayak Kumar (2008) analysed trough LCA analysis the environmental impact of Jotun Paints, spanning from raw material extraction to product disposal. Two methodologies were employed: one measures the embodied carbon footprint, encompassing emissions from extraction to customer delivery and application; the other generates a single environmental performance score based on 11 impact categories. The goal was to provide detailed carbon footprint figures and a comprehensive environmental score aligned with the Planet Positive Protocol. The scope covered all lifecycle stages, including end-of-life disposal scenarios, direct suppliers, manufacturing energy, product packaging, and compound emissions during application.

Yacout, D., & El-Zahhar, M. A. (2018) investigates the environmental impact of global paint production, particularly focusing on "White Alkyd Enamel Paint." Employing Life Cycle Assessment (LCA), the study identifies that white alkyd enamel paint production significantly affects resources (45.8%), ecosystem quality (31.8%), and human health (22.5%), with fossil fuels depletion being the primary contributor (44.8%). Alkyd resin production emerges as a key impact source, suggesting potential mitigation through energy management. The study recommends further research, including different paint types and colour comparisons, while underscoring the need for more local-level LCA studies to minimize the global environmental footprint of the paint industry.

Product Environmental Footprint Category Rules (PEFCR) – Decorative Paints, (2018) serves as a detailed guide for conducting environmental studies on decorative paints. It outlines the purpose, applicability, and development criteria, emphasizing compliance with standards. The document is applicable to products sold in the European Union + EFTA, covering specific paint categories. The PEFCR provides analysis of representative products sold in the EU + EFTA market under the cradle-to-grave system boundary, which include raw material extraction, manufacturing, use phase and end-of life of the product.

4.2.3 Overview of LCA results from literature review

Among the six chosen studies, four specifically address paint formulation. These studies include PAIANO, Annarita, et al. (2021), PAIANO, Annarita, et al. (2020), Ganesh Nayak and Vinayak Kumar (2008) and Yacout, D., & El-Zahhar, M. A. (2018). It is important to highlight that Ganesh Nayak and Vinayak Kumar (2008) and PAIANO, Annarita, et al. (2020) and (2021) studies were based on manufacturing company's data, thereby representing an average of a product produced by specific companies. While Yacout, D., & El-Zahhar, M. A. (2018) collected data from a local case study plant for paint production located in Egypt during 2018 and the Background data was compiled using the available data in the EcoInvent data base.

NEUWIRTH, Josefin, et al (2022) presented in the study the direct human toxicity potential, for both inhalation and dermal, for indoor wood paint. The formulation utilized the representative product for indoor wood paint outlined in the PEFCR for decorative paint (Figure 3-1). The findings indicate that the most significant contributors to the total ProScale score, in both inhalation and dermal exposure, were the application and raw material production stages. Specifically, titanium dioxide played a predominant role in influencing the total ProScale score during the application step. Additionally, for dermal exposure, calcium carbonate also contributed significantly to the total ProScale score during the application phase.

PAIANO, Annarita, et al. (2021) presented the environmental impact results of two different product types of paint, Acrylux and Mastercolor Plus manufactured by Vitalvernici s.r.l., which is an Italian manufacturer of plastic coatings and paint. For each product, two additional and alternative scenarios have been hypothesised. Acrylux proves to have less environmental impact compared to Mastercolor Plus, with the only exception being the abiotic depletion potential for fossil resources (ADPE), where Mastercolor Plus has a lower impact.

The production of silicone significantly impacts both products due to high energy requirements in its production and refining phases, making it the primary contributor to environmental indicators except for ADPE and POCP. Resins also play a substantial role. Calcium carbonate, carboxymethyl, and carboxymethyl cellulose exhibit higher environmental impacts due to extraction and production processes. Notably, chromium oxide has a significant impact on ADPE due to inefficiencies in its production process. The alternative scenarios A and B, compared to the baseline scenario, show a general reduction of environmental impacts GWP performs the best, decreasing by 50.3% in scenario A and 49.8% in scenario B.

PAIANO, Annarita, et al. (2020) LCA was carried out for seven products manufactured by Vitalvernici s.r.l., which is an Italian manufacturer of plastic coatings and paints. Then, the authors averaged the values of all impact indicators for each category assigning to product 1 and product 2. Results highlighted that product 2 has lower environmental impacts than product 1 in both modules A1 and A2. In module A3 product 2 has a higher impact caused by the higher energy consumption in the manufacturing process.
Silicone, with high energy requirements in production and refining, was the major contributor to the production and supply of raw materials, affecting ADPF, AP, EP, GWP, and ODP emissions. In contrast, chromium oxide, carboxymethyl, and resins predominantly influenced ADPE. Calcium carbonate significantly impacted POCP due to its environmental effects during extraction, production processes, and high-temperature phases. While transportation's overall impact was minimal, powder transport by ship had the greatest influence in module A2, except for ADPE, which was mostly influenced by pigment and powder transport by road. In module A3, polypropylene for packaging manufacturing emerged as the most impactful contributor in ADPF, AP, GWP, and POCP, with blowing processes and energy consumption strongly affecting ADPE, EP, and ODP.

Ganesh Nayak and Vinayak Kumar (2008) analysed five paints produced by Jotun Paints, Abu Dhabi, in the calendar year 2007, comprising three solvent-based and two water-based paints. The results revealed that the total carbon footprint of solvent-based paints is approximately three times higher than that of water-based paints. This disparity is attributed to the utilization of organic solvents in solvent-based paints, contrasting with the water used in water-based paints.

The manufacturing of raw materials constitutes an average of 72 percent of the total carbon footprint for solvent-based paints, with paint disposal at the end of its life also contributing significantly. In the case of water-based paints, emissions vary by product, with one following solvent-based emissions and another where the majority of emissions occur during the disposal phase.

For solvent-based paints, resins and pigment are the primary contributors to the total carbon footprint, while among water-based paints, energy, final delivery, and waste disposal play crucial roles, followed by binder. Overall, water-based paints demonstrated lower climate change impact compared to solvent-based paints.

Yacout, D., & El-Zahhar, M. A. (2018) assessed the environmental impacts of “White alkyd enamel paint” production in Egypt. According to the LCA analysis, resource extraction is the most significant impact category in white enamel production, followed by ecosystem quality and human health. Fossil fuels depletion ranks as the most impactful category, succeeded by land use and respiratory inorganic formation potential. Climate change contributes to 3.5% of the overall impacts. The study identifies alkyd resin and Titanium dioxide, the primary raw materials in the production process, as the major contributors to various impact categories.

Product Environmental Footprint Category Rules – Decorative Paints (PEFCR) 2018 evaluate four representative products and derive a European average formulation for decorative paints. The focus is on indoor and outdoor variations, including indoor and outdoor wall paint, as well as indoor and outdoor wood paint. Utilizing Product Environmental Footprint Category Rules (PEFCR), the study employs a cradle-to-grave approach, with the functional unit set as 1m2 of substrate for 50 years at a specified quality level (minimum 98% opacity). It's important to clarify that the PEF is not designed as a comparative LCA, emphasizing the absence of direct comparisons between different paints' environmental impacts. Despite this, the results obtained shed light on the environmental impact of an average market paint, providing a foundation for defining limits to curtail the environmental footprint within the painting industry.

4.2.3.1 Formulations

The composition of paints and varnishes depends on the distribution of four key components according to the paint purpose: decorative, protective, or specific technical properties. The formulation also changes according to substrates on which they are applied and useful life.

- Resin/Polymer: This element, encompassing resins like alkyd, vinyl, bitumen, and polyurethane, imparts chemical and physical properties such as hardness, flexibility, and water resistance to the dried film.
- Pigment: Responsible for colour and opacity, pigments like titanium dioxide (TiO2), iron oxide (for red and ochre shades), and carbon black (for black hues) also influence certain physical properties of the paint.
- Solvent: Including organic solvents such as alcohols, esters, and ketones, solvents are typically added to water. They enable the spread of resin and pigment on surfaces and prevent paint hardening.
- Additives: These components, though minor in quantity, play a crucial role in enhancing paint functionality. Additives improve mould resistance, spread rates, prevent foaming, and extend shelf life. Despite being a small portion of paint composition, there are hundreds of types of additives.

From the chosen studies, a paint formulation was derived, as presented below. However, the studies did not differentiate the painting for indoor or outdoor purposes. Additionally, no formulation for varnishes were found in the literature review.

Indoor paint and outdoor paint from the literature review

For the LCA study *NEUWIRTH, Josefin, et al (2022)* used the formulation based on the representative product for indoor wood paint from the PEFCR (2018) for decorative paint as shown in Table 25.

Table 25. Based on the formulation presented in the LCA analysis for indoor wood from NEUWIRTH, Josefin, et al. (2022).

Raw material	Weight percentage (%)
Tap water	31.25
Styrene Acrylate dispersion (SA), 50% in water	21.00
Titanium dioxide	10.90
Ground calcium carbonate, dry	27.15

Raw material	Weight percentage (%)
Kaolin (China clay)	4.25
Propylene glycol	0.40
Additive, unspecified	5.05

Source: NEUWIRTH, Josefin, et al. A ProScale case study on indoor wall paint. 2022

PAIANO, Annarita, et al. (2021) presented a paint formulation per kg of produced paint based on inputs from the Italian manufacture Vitalvernici s.r.l. as presented in Table 26.

Table 26. Paint formulation used as input from PAIANO, Annarita, et al. (2021).

Material (input)	Ecoinvent modules	Amount (per kg)	
		Mastercolor Plus	Acrylux
Additives (kg)			
Ethylene glycol	RER: ethylene glycol production	1.64E-02	1.64E-02
Acrylic acid production	RER: acrylic acid production	7.32E-03	7.32E-03
Sodium phosphate production	RER: sodium phosphate production	3.51E03	3.51E-03
Chemical inorganics	GLO: chemical production, inorganic	6.09E-03	6.09E-03
Wax production	GLO:wax production, for lost-wax metal casting	5.86E-03	5.86E-03
Solvent production	GLO: solvent production, organic	2.93E-03	2.93E-03
Latex production	RER: latex production	5.50E-03	5.50E-03
Ammonia liquid	RER: Ammonia production, steam reforming liquid	2.05E-03	2.05E-03
Paraffin	RER: paraffin production	3.66-04	3.66E-04
Pigments (kg)			
Benzimidazole compound	RER:benzimidazole-compound production	1.67E-02	1.67E02
Chromium oxide flakes	RER:chromium oxide production, flakes	1.67E-02	1.67E02
Titanium dioxide	GLO: rutile production, synthetoic, 95% titanium dioxide, Becher process	1.67E-02	1.67E02
Powders (kg)			
Sodium phosphate	RER: sodium phosphate production	6.29E-04	4.32E-04
Silicone	RoW: silicon production, electronics grade	7.23E-02	4.96E-02
Titanium dioxide	RER: titanium dioxide production, sulfate process	4.08E-02	2.80E-02

Material (input)	Ecoinvent modules	Amount (per kg)	
		Mastercolor Plus	Acrylux
Kaolin	RER: kaolin production	3.57E-03	2.45E-03
Calcium carbonate	RER: calcium carbide production, technical grade	3.56E-01	2.45E-01
Sand	GLO: market for sand	1.82E-02	1.25E-02
Talc	RER: magnesium oxide production	1.56E-02	1.07E-02
Carboxymethyl cellulose	RER: carboxymethyl cellulose production, powder	2.39E-03	1.64E-03
Resins (kg)			
Cationic resin	RER: Acrylic dispersion production, production, product in 65% solution state	2.10E-01	4.50E-01
Water (kg)			
Tap water	Europe without Switzerland: tap water production, underground water without treatment	2.09E-01	9.64E-01Grid electrical energy
Energy (Mj)			
Grid electrical energy	IT: market for electricity, low voltage	1.45E-01	8.09E-02
Photovoltaic energy	IT: electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted	4.02E-01	2.24E-01
Output - Waste (kg)			
Sludge	Europe without Switzerland: treatment of wastewater	2.64E-02	2.64E-02
Paper and cardboard	Europe without Switzerland: treatment of waste paperboard, sorting plant	4.91E-03	4.91E-03
Plastic	Europe without Switzerland: treatment of waste plastic, mixture, sanitary landfill	1.77E-02	1.77E-02
Water (kg)			
Wastewater	Europe without Switzerland: market for wastewater, average	2.88E-02	8.64E-01

Source: PAIANO, Annarita, et al. Sustainable options for paints through a life cycle assessment method. Journal of Cleaner Production, 2021, 295: 126464.

The same Italian manufacture company, Vitalvernici s.r.l provide the formulation based on the yearly amount used to produce paint products. Table 27 presents the formulation used by *PAIANO, Annarita, et al. (2020).*

Table 27. Show the inputs used in the paint formulation to produce painting during a year using data from Vitalvernici s.r.l.

Raw materials	Quantity supplied (kg)
Additives	40,227
Pigments	6,620
Powders	810,975
Resins	198,105
Water	267,135
Total:	1.323,062

Source: PAIANO, Annarita, et al. An environmental life cycle assessment of paints and varnishes in the Italian production process. XIV Convegno della rete Italiana LCA IX Convegno dell'Associazione Rete Italiana LCA, 2020, 165.

The formulation used by *Yacout, D., & El-Zahhar, M. A. (2018)* is presented in Table 28 and show the formulation used to produce "White alkyd enamel paint" in a manufacture in Egypt.

Table 28. Inputs to produce White alkyd enamel paint based on data from a manufacture in Egypt.

Item	Unit	Amount
Input		
Raw materials		
Alkyd resin	kg	520
Titanium dioxide	kg	200
Dolomite	kg	140
Cobalt	kg	3,6
Calcium	kg	4,8
Zirconium	kg	17
White spirit	kg	100
Bentonite (clay)	kg	5
Dispersing agent:		
Polycarboxylate	kg	5
Energy		
Electricity for mixing, milling and packing	Whr	25
Output		
End product (paint)	kg	1000

Item	Unit	Amount
<u>Emissions to air</u>		
Suspended dust/Particulate matter	ppm	213,5
HC	ppm	166

Source: Yacout, D., & El-Zahhar, M. A. (2018). Environmental impact assessment of paints production in Egypt. In Proceedings—4th international conference of biotechnology, environment and engineering sciences ICBE (pp. 60-65).

Ganesh Nayak and Vinayak Kumar (2008) did not provide the amount of raw material that went to each of the five-product analysed in the LCA. However, a table presenting which raw material was used in the manufacturing was provided as shown in Table 29, where the "X" demonstrated that the material is part of the paint and "-" represent an empty box.

Table 29. Raw materials used to produce the 5 analysed paint from Jotun.

Material Function	Penguard HB	Penguard Texo	Durathane White	Jotashield Alkali Resistant Primer	Jotashield Thermo
Resin	X	X	X	-	-
Solvent	X	X	X	X	X
Thickener	X	X	X	X	X
Additive	X	X	X	X	X
Pigment	X	X	X	X	X
Extender	-	X	-	X	-
Binder	-	-	-	X	X
Filler	-	-	-	-	X

Source: Ganesh Nayak and Vinayak Kumar (Jotun Abu Dhabi L.L.C.) – Jotun Paints (2008), showing raw materials used for each paint from the LCA study.

The Product Environmental Footprint Category Rules for Decorative Paints (PEFCR), 2018 divide their analysis in indoor and outdoor paint as presented respectively in Table 30 and Table 31.

Table 30. Table from the Product Environmental Footprint Category Rules – Decorative Paints (PEFCR) 2018.

Indoor wall averaged paint	
<u>Raw Material</u>	%
Chemical Substances	
Tap water for paint, at user	31.25
Styrene Acrylate dispersion (SA), 50% in water	21.00

Indoor wall averaged paint	
Titanium dioxide	10.90
GCC dry	27.15
China clay, calcinated	4.25
Propylene glycol	0.40
Additive, unspecfied	5.05
Other characteristics for the PEF calculation	
VOCs (g/L)	5.184
Dry mass (g/kg)	578.5
Biocides (% w/w)	0.05
Type of biocides	BIT
Quality level based on durability scheme	Indoor wall Q2
Maintenance multiplier	8.33
Coverage test data (m2/L) CR 98%	9.50
Production losses (in %)	3
Paint density (kg/L)	1.43

Source: Product Environmental Footprint Category Rules – Decorative Paints (PEFCR) 2018

Table 31. From Product Environmental Footprint Category Rules – Decorative Paints (PEFCR) 2018.

Outdoor wall averaged paint	
Raw Material	%
Chemical Substances	
Tap water for paint, at user	20.30
GCC dry	17.00
Titanium dioxide	12.80
Styrene Acrylate dispersion (SA), 50% in water	43.00
Ester alcohol	2.00
Monoethylene glycol (MEG)	0.50
Additives, unspecified	4.40
Other characteristics for the PEF calculation	

Outdoor wall averaged paint	
VOCs (g/L)	6.5
Dry mass (g/kg)	557.0
Biocides (% w/w)	0.05
Type of biocides	BIT
Quality level based on durability scheme	Outdoor wall Q2
Maintenance multiplier	5.00
Coverage test data (m2/L) CR 98%	7.00
Production losses (in %)	3
Paint density (kg/L)	1.30

Source: Product Environmental Footprint Category Rules – Decorative Paints (PEFCR) 2018

Varnishes

From the literature review focusing on finding formulations for paints and varnishes (rather than needing it to be full LCAs), no varnish formulation was found, and thus no representative formulation is presented in this section for varnishes.

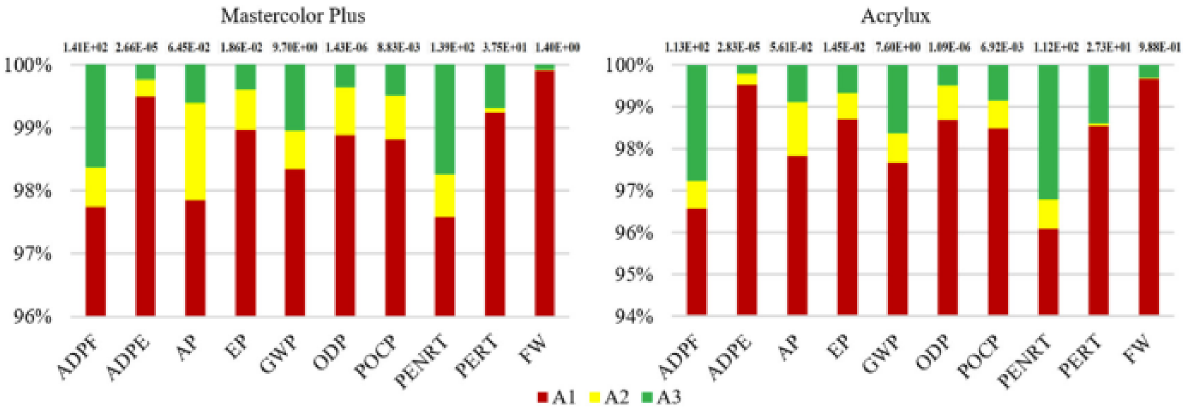
4.2.3.2 Human health impacts

Compiling conclusions from various Life Cycle Assessment (LCA) studies conducted by different authors proves challenging due to several factors. Altering the functional unit impacts absolute results, while modifications to assumptions, allocations, LCA methodology, Life Cycle Inventory (LCI) datasets, and system boundaries affect both absolute and relative outcomes.

The literature review highlighted a predominant focus on the global warming potential (GWP) of paintings in various studies, overlooking critical impacts such as human health associated with VOC emissions. The Photochemical Ozone Creation Potential (POCP) category serves as a means to assess these emissions.

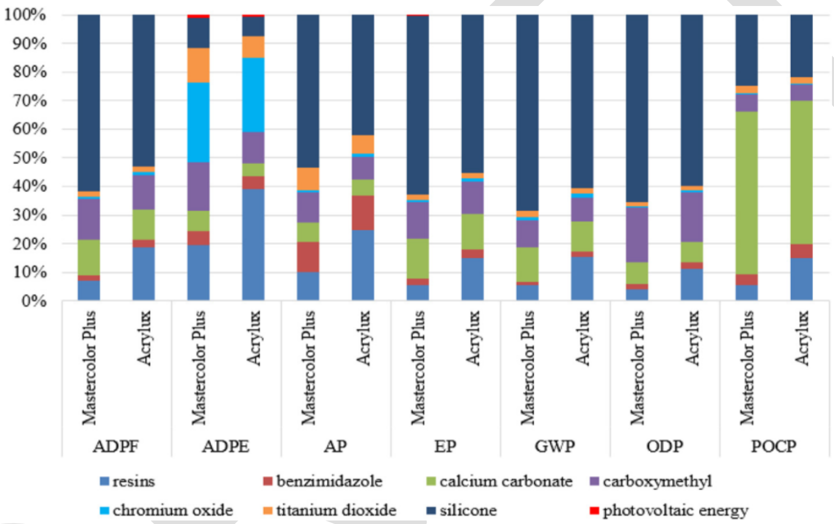
PAIANO, Annarita, et al. (2021) delved into the impact of POCP along with other LCIA indicators, including Abiotic Depletion Potential for Fossil Resources (ADPF), Abiotic Depletion Potential for Non-fossil Resources (ADPE), Acidification Potential (AP), Eutrophication Potential (EP), GWP, and Ozone Depletion Potential (ODP). However, their study exclusively addressed emissions from the production phase (A1-A3) as presented in Figure *15*, leaving the impacts from the use phase, where VOC is released, not fully examined. The impacts related to the production phase assessed by PAIANO, Annarita, et al. (2021) are visualized in Figure *16* to Figure *18*.

Figure 15. A1-A3 environmental indicators.



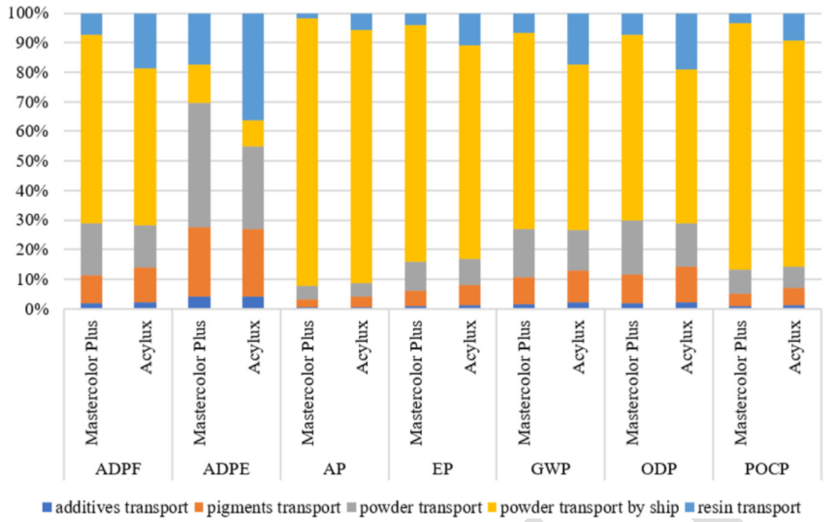
Source: PAIANO, Annarita, et al. Sustainable options for paints through a life cycle assessment method. Journal of Cleaner Production, 2021, 295: 126464

Figure 16. Module A1 composition for environmental indicators.



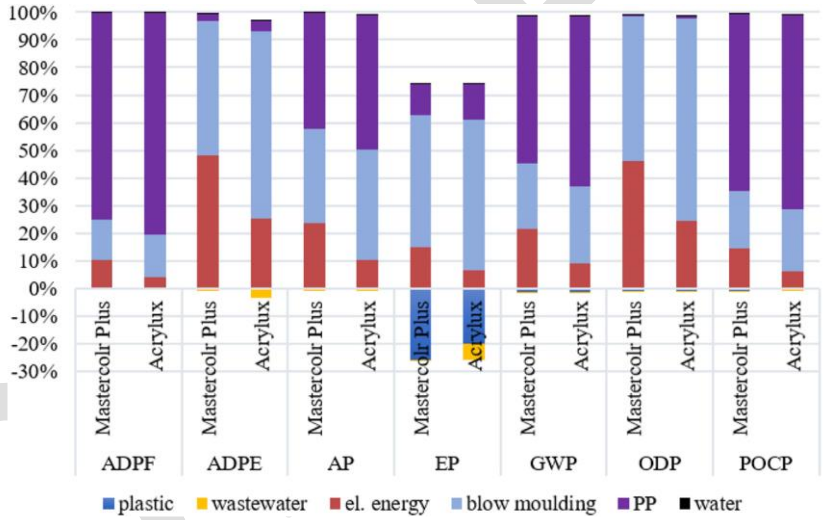
Source: PAIANO, Annarita, et al. Sustainable options for paints through a life cycle assessment method. Journal of Cleaner Production, 2021, 295: 126464

Figure 17. Module A2 composition for environmental indicators.



Source: PAIANO, Annarita, et al. Sustainable options for paints through a life cycle assessment method. Journal of Cleaner Production, 2021, 295: 126464

Figure 18. Module A3 composition for environmental indicators.

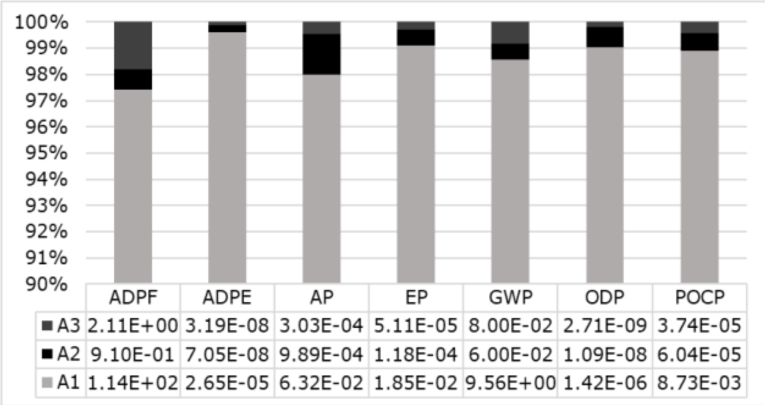


Source: PAIANO, Annarita, et al. Sustainable options for paints through a life cycle assessment method. Journal of Cleaner Production, 2021, 295: 126464

Overall, there is a substantial disparity observed in the total impact indicator results between the two examined products in the baseline scenario. Acrylux emerges as the more environmentally benign product across the majority of considered indicators when compared to Mastercolor Plus. Specifically, Mastercolor Plus exhibits a 24% higher Ozone Depletion Potential (ODP), while its Global Warming Potential (GWP), Eutrophication Potential (EP), and Photochemical Ozone Creation Potential (POCP) are all 22% higher than those of Acrylux. In the case of POCP, it appears that most emissions may stem from calcium carbonate, responsible for improving paint properties such as sheen, opacity (covering power), and wear resistance.

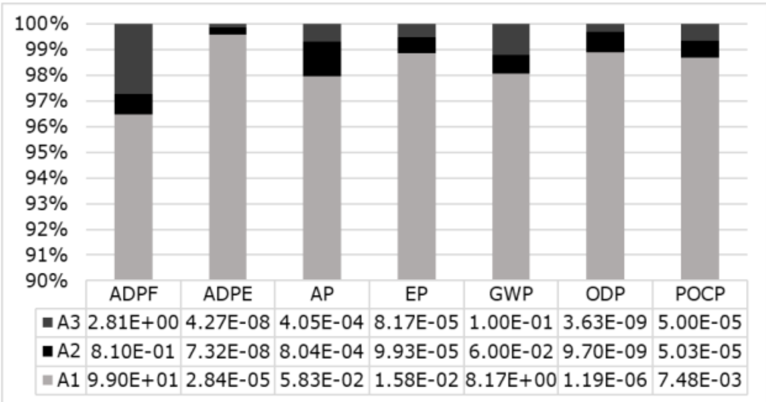
For the assessment made by PAIANO, Annarita, et al. (2020) where 2 average products were compared, the same result showing the A1 as the responsible for the majority of the POCP emissions as presented Figure *19* and Figure *20*. Among the modules analysed, module A1 has a higher weight, due to the supplied silicone followed by chromium oxide, carboxymethyl and resins. Results also presented Calcium carbonate, with a great environmental impact due to the extraction, production process and the high temperatures reached during the production phase, greatly influenced POCP for over 55%.

Figure 19. Modules incidence: product 1 environmental indicators.



Source: PAIANO, Annarita, et al. An environmental life cycle assessment of paints and varnishes in the Italian production process. XIV Convegno della rete Italiana LCA IX Convegno dell'Associazione Rete Italiana LCA, 2020, 165.

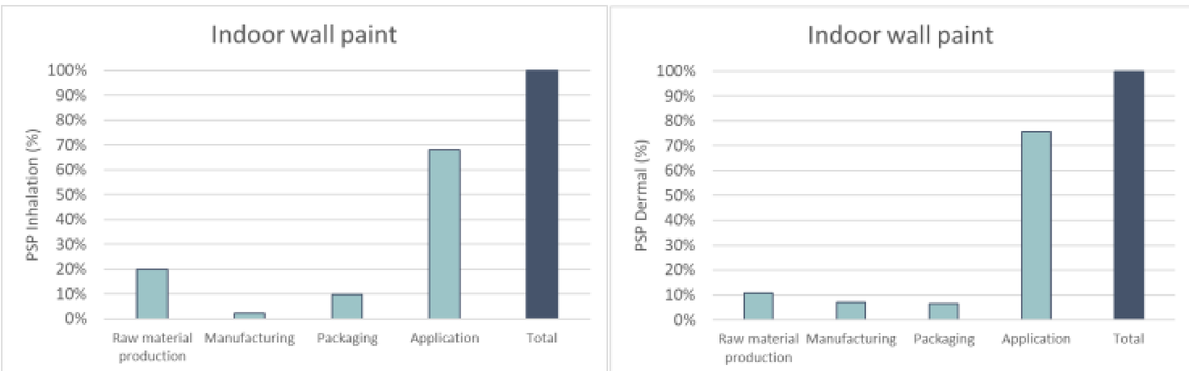
Figure 20. Modules incidence: product 2 environmental indicators.



Source: PAIANO, Annarita, et al. An environmental life cycle assessment of paints and varnishes in the Italian production process. XIV Convegno della rete Italiana LCA IX Convegno dell'Associazione Rete Italiana LCA, 2020, 165.

In addition, NEUWIRTH, Josefin, et al (2022) present findings focused on the direct human toxicity impact, specifically addressing inhalation and dermal toxicity potential related to indoor wall paint. The assessment indicates that the application phase contributes the most to the overall ProScale score, for both inhalation and dermal exposure, with raw material production following closely, as illustrated in Figure 21.

Figure 21. ProScale result for inhalation (left) and dermal (right) toxicity for an average indoor wall paint.

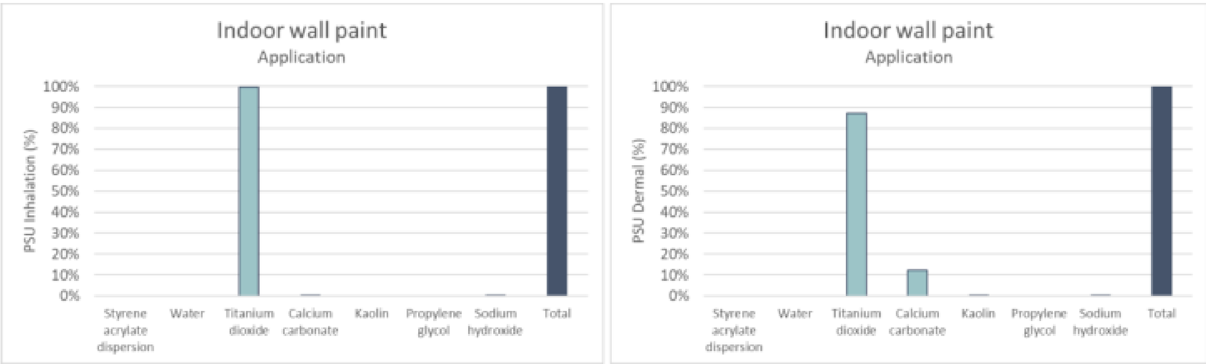


Source: NEUWIRTH, Josefin, et al. A ProScale case study on indoor wall paint. 2022.

The results highlight titanium dioxide as the primary contributor to the overall ProScale score during the application step. In the case of dermal exposure, calcium carbonate also plays a significant role in contributing to the total ProScale score during the application phase, as depicted in Figure 22.

The evaluation of indoor wall paint underscores that the application phase has the most substantial impact on final emissions, both in terms of inhalation and dermal exposure. The modelling of the application phase proves to be a critical factor influencing the ultimate results.

Figure 22. ProScale results for inhalation (left) and dermal (right) of the application for an indoor wall.



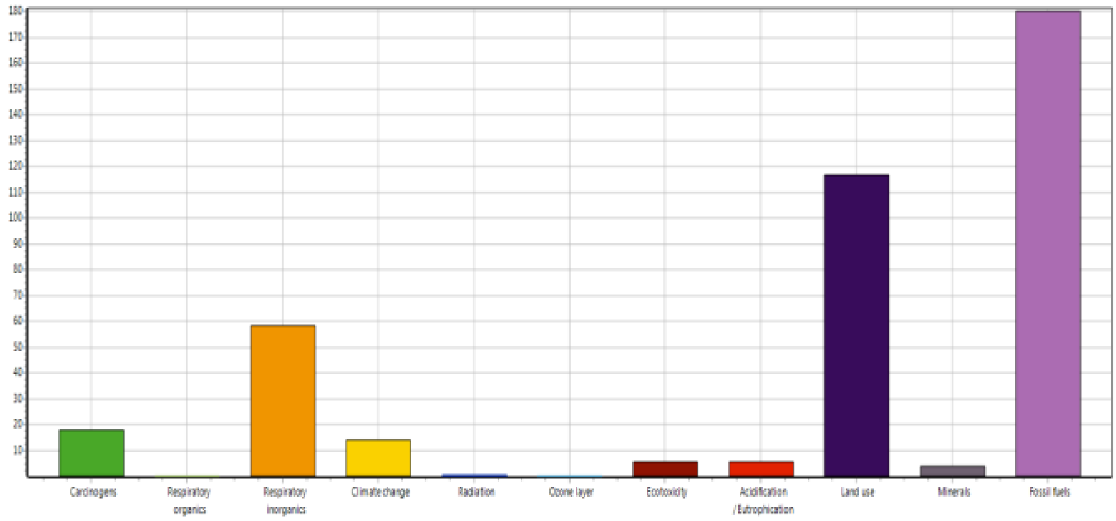
Source: NEUWIRTH, Josefin, et al. A ProScale case study on indoor wall paint. 2022.

For the manufacturing of white enamel alkyd paint Yacout, D., & El-Zahhar, M. A. (2018) determined that respiratory inorganics and carcinogens contribute as the third and fourth highest impacts, respectively.

The third most substantial category is the formation potential of respiratory inorganics, constituting 14.6% of the overall impact. These impacts result from air emissions during the combustion of fossil fuels, leading to aerosols containing sulphate and nitrates. Additionally, the use of fossil fuels in alkyd resin production contributes to air emissions. In the sulphate process for manufacturing titanium dioxide, the use of Sulphuric Acid to dissolve the feedstock yields by-products such as ferrous sulphate monohydrated (MON), red gypsum, and ferrous sulphate heptahydrated. As for carcinogenic potential, Figure 23 illustrates that this category accounts for 4.4% of the total impact, primarily due to emissions of Arsenic and cadmium from Alkyd resin production.

Figure 23. Environmental impacts per category in the white enamel Alkyd paint production.

Impact category	Total (%)
Fossil fuels	44.8
Land use	29.1
Respiratory inorganics	14.6
Carcinogens	4.4
Climate change	3.5
Acidification/ Eutrophication	1.4
Ecotoxicity	1.3
Minerals	0.9
Respiratory organics	0.1
Radiation	-
Ozone layer	-



Source: YACOUT, Dalia; EL-ZAHHAR, Mohamed Ahmed. Environmental impact assessment of paints production in Egypt. In: Proceedings—4th international conference of biotechnology, environment, and engineering sciences ICBE. 2018. p. 60-65.

In summary, the literature evaluation revealed that the emissions associated with POCP predominantly originate from the A1 phase, pertaining to raw materials, according to PAIANO, Annarita, et al. (2020, 2021) in Figure *15*, Figure *19*, Figure *20*. In contrast, NEUWIRTH, Josefin, et al. (2022) identify the A1 phase as the second-highest contributor, following the application phase. However, direct comparison is hindered by the absence of a use phase assessment in PAIANO, Annarita, et al. (2021), where the application takes precedence. Consequently, a comprehensive evaluation of emissions throughout the entire life cycle is challenging.

Moreover, PAIANO, Annarita, et al. (2021) emphasize that silicone production has the highest impact in the A1 phase. Conversely, NEUWIRTH, Josefin, et al. (2022) attribute the most significant impact related to human toxicity to Titanium dioxide. Yacout, D., & El-Zahhar, M. A. (2018) also link respiratory inorganic emissions to titanium dioxide production and introduce the combustion of fossil fuels as a contributing factor. Concerning the impact of carcinogens, emissions are associated with Arsenic and ca

mium from Alkyd resin production.

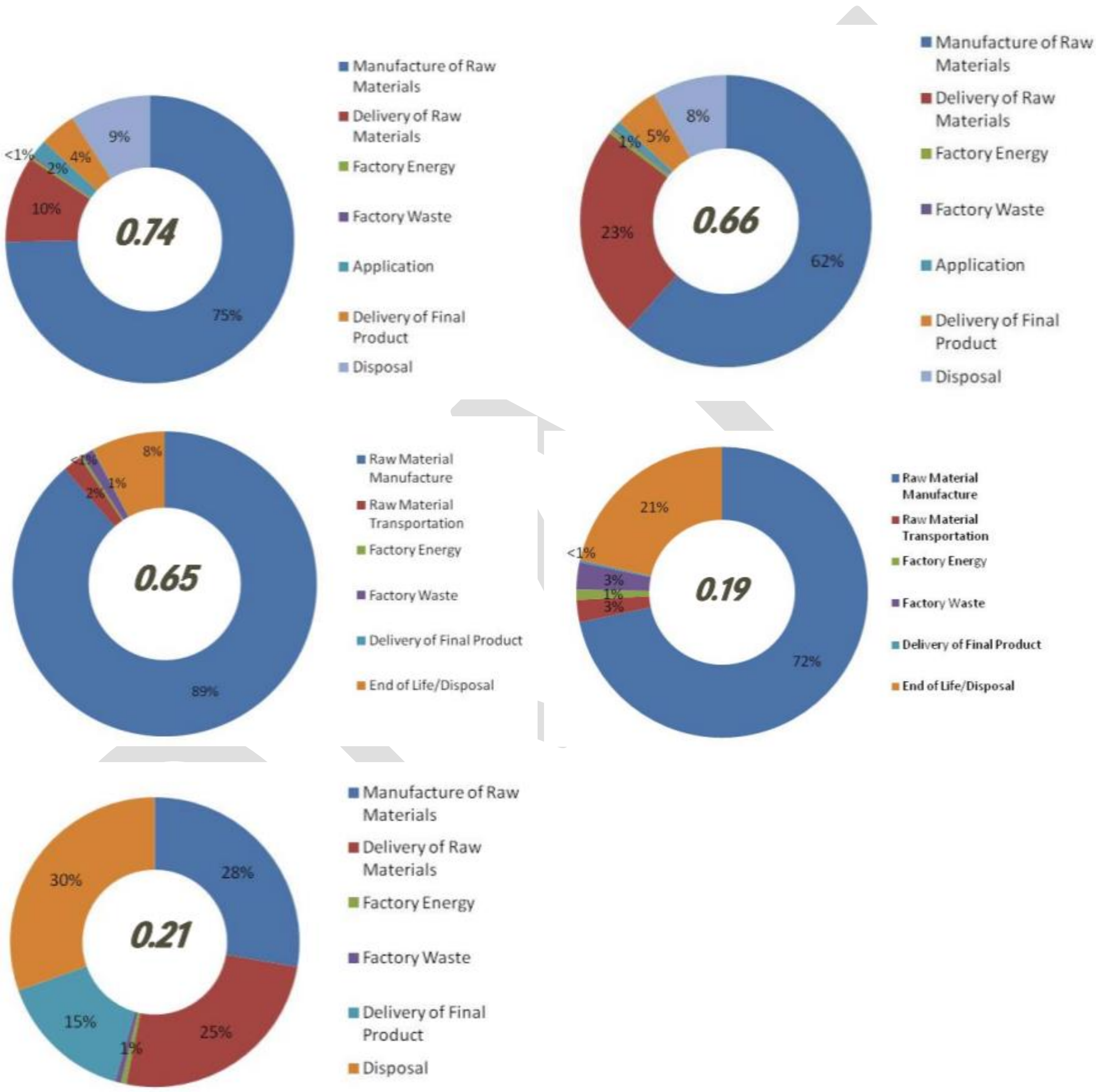
This discrepancy in results may be attributed to the specific composition of paints, where each product contains varying amounts of silicone and titanium dioxide, directly influencing the final outcomes. Additionally, it is crucial to emphasize that, despite the categories having different names, they all assess human health impacts according to the employed methodologies.

4.2.4 Environmental/Ecosystem related impacts

As presented in 4.2.3.2 section synthesizing an environmental related impact from various LCA studies conducted by different researchers presents challenges due to several factors that can affect both absolute and relative outcomes.

Ganesh Nayak and Vinayak Kumar (2008) exclusively evaluated the CO2eq impact of five distinct paint productions from cradle to grave. The findings indicated that the manufacturing of raw materials had the highest impact in four out of five paintings, with only one paint exhibiting the highest impact in the disposal phase. Nevertheless, the difference between these two categories is only 2% as presented in Figure *24*.

Figure 24. Total embodied carbon by life cycle stages.



Source: Ganesh Nayak and Vinayak Kumar (Jotun Abu Dhabi L.L.C.) – Jotun Paints. 2008

In Figure *15* PAIANO, Annarita, et al. (2021) illustrated that GWP had the highest impact compared to all the assessed impact categories, with 9.70 kgCO2eq and 7.60 kgCO2eq per kg of paint for the analysed product in the study, representing 49.7% and 51.1%, respectively. As depicted in Figure 10, the results indicated that A1 had the highest impact among environmental categories such as ADPF, ADPE, AP, EP, GWP, and ODP, with silicone and calcium carbonate being the materials responsible for most of the emissions, respectively. In a previous study from 2020, PAIANO, Annarita, et al. also concluded that A1 was responsible for the majority of the environmental impact from paint production.

Yacout, D., & El-Zahhar, M. A. (2018) also assessed fossil fuel (CO2eq) emissions as the highest environmental impact related to the production phase. Additionally, land use emerged as the second-highest impact, as presented in Figure 16. This high impact can be attributed to the influence of oil used in manufacturing and ilmenite ore used in the production of titanium dioxide. The used oil in the manufacturing process of resin, as one of its inputs, is extracted from large amounts of vegetation crops such as cotton seeds or soybeans.

4.2.5 Conclusion

The literature review underscores that the majority of LCAs in the field of painting concentrate predominantly on building materials where the paint is applied, emphasizing the end-of-life considerations for the material containing paint. However, the chosen literature primarily focuses on the production phase of painting, omitting the assessment of the use and end-of-life phases. These stages, underscored by NEUWIRTH, Josefin, et al. (2022) and Ganesh Nayak and Vinayak Kumar (2008), carry a significant human health impact. This limitation in scope poses a challenge when attempting to compare the overall impact of the painting industry, especially when dealing with diverse function units and assessed phases.

Another notable challenge identified in the literature review is the scarcity of information regarding paint formulation. Many sources provide the primary composition and percentage of ingredients in the formulation, posing a barrier to the identification and comparison of different types of paints formulation and ingredients. This limitation hinders the establishment of an average paint formulation representative of the European market.

Overall, the literature review emphasizes the significant environmental impact of the production phase (A1), particularly in terms of GWP. Furthermore, studies underscored impacts related to human health and toxicity, with a focus on POCP, respiratory inorganics, and carcinogens. However, the available literature related to the LCA assessment of paints and varnishes is insufficient to draw conclusions regarding an average formulation or to pinpoint the most harmful impacts from cradle to grave. Consequently, an additional study is introduced in Section 4.3 exploring paint formulations to provide a representative formulation for the European market.

4.3 LCA screening results

While there were few LCA studies on paint and varnish products found in the literature review, which only provided very limited information on the paint and varnish formulas, a further LCA screening was performed according to the PEFCR for Decorative Paints[128]. This section presents the results of that screening for indoor paint, outdoor paint, and varnish, respectively.

4.3.1 Methodology

The Product Environmental Footprint (PEF) is a type of LCA to measure the environmental performance of a product or service via multiple environmental parameters and across the product or service life cycle. The purpose of a PEF methodology is to account for all activities throughout the lifecycle in a standardised way for each product category to ensure comparability of results on a European level. As far as the authors are aware, there are currently no valid PEFCRs for paints and varnishes (the only previously published draft PEFCR for Decorative Paints expired at the end of 2020). Consequently, a number of LCA screening studies have been carried out following the general PEF methodology set out in Commission Recommendations 2021/2279 and 2021/9332.

For clarity, it is noted that these studies have not been carried out with the intention of creating PEF category rules for decorative paint products. The main purpose is instead to screen for LCA hotspots and to use this information to help provide context and supporting rationale for criteria proposals in the revision process of EU Ecolabel criteria for decorative paint products.

A PEF study has a number of phases which should be completed: Goal definition; Scope definition; Life cycle inventory (LCI); reporting of Environmental Footprint Impact Assessment (EFIA) results; and Interpretation of results. Consequently, the following sections are split into these phases. The first few sections will describe the goal and scope definition for all the PEF studies as these are consistent for all the PEF studies, whereas the LCI, LCIA, interpretation and reporting will be split for each of the studies as these vary.

[128] See: Product Environmental Footprint Category Rules - Decorative Paints

4.3.1.1 Goal Definition

The purpose of the goal definition is to set the context of the study. The goal definition should answer what the aim of the study is, what its intended applications are, who is commissioning the study and who is the target audience.

The goal of this study is to quantify the potential environmental impact and hotspots of three groups of decorative paint products across their entire life cycle. The three groups of paint products are:

1. outdoor wall paint,
2. indoor wall paint,
3. outdoor wood varnish.

The composition of each of the paint groups will be further elaborated in the respective sections below. The results of the studies will be used in the revision of the EU Ecolabel criteria for decorative paint products in terms of identifying areas within the life cycle of the three groups of paint products where existing or new criteria will have a significant positive effect on the environmental performance of the products.

This study represents average groups of decorative paint products in Europe and does not represent individual brands or products. Hence, the study will give an overall picture of the environmental performance of paints and varnishes. No comparisons between the products are made.

The commissioner of the study is the European Commission in the form of the Joint Research Centre and the target audience is relevant stakeholders (e.g. producers, associations).

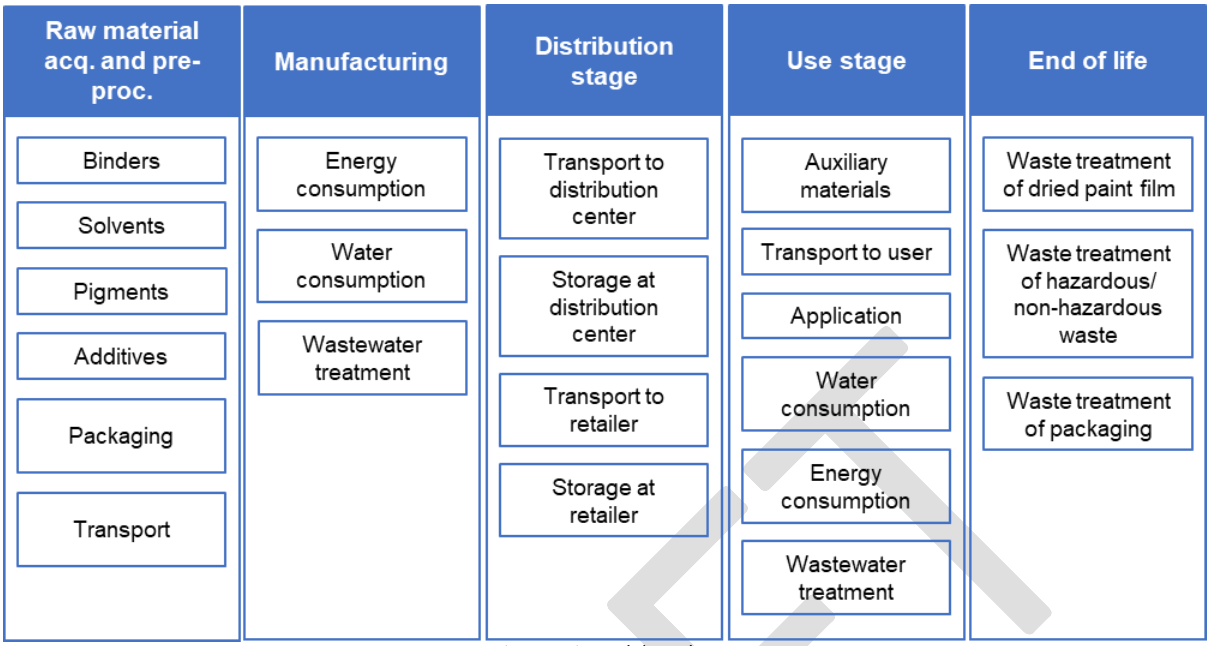
4.3.1.2 Scope definition and impact categories

The scope of the study describes what the system to be evaluated contains, as well as possible technical specifications. The scope should include the system boundaries, assumptions and limitations and impact categories that will be considered. As a few different products are being studied, which have a number of different reference flows and functional units between them, these are not mentioned until the section where results are reported.

4.3.1.2.1 System description and boundaries

The system boundaries were defined according to the PEF methodology. Hence, including the life cycle stages: raw material acquisition and pre-processing (LCS1), manufacturing (LCS2), distribution stage (LCS3), use stage (LCS4), and End-of-Life (LCS5). Thus, this study is a cradle-to-grave study. Figure *25* presents the five life cycle stages and their appertaining processes included in the study.

Figure 25. Schematic representation of the life cycle stages and processes included in the PEF studies for the selected paints and varnishes products.



Source: Own elaboration.

It is assumed that all raw materials and packaging are sourced within Europe, for which reason the pre-defined distances and transportation modes from the PEFCR for Decorative Paints have been used.

The raw material acquisition, production, construction, and end-of-life of the substrate are excluded from the system boundaries.

Raw material acquisition and pre-processing: This life cycle stage starts with the extraction of resources from nature and ends with the production of product components. Specifically, this stage includes mining and extraction of resources; pre-processing of material input to the product in scope, this also includes recyclable materials; transportation within and between raw material acquisition and preprocessing facilities and to the production facility; finally, it includes the production of packaging materials. For all these processes, the energy and natural resources needed to produce any intermediary products are also included.

Manufacturing: This life cycle stage starts with the product components entering the production facility and ends with the final product leaving the premises. It includes chemical processing; manufacturing (mixing of formulation, filling of cans, and labelling); furthermore, it includes the treatment of wastewater and other waste generated during manufacturing. The commuting of employees, administrative services, and capital goods such as machinery used in the paint production process, buildings, or office equipment are excluded from the system boundaries.

Distribution stage: This life cycle stage starts when the final product leaves the manufacturing facility. This stage includes transport from factory gate to the Regional Distribution Centre (RDC) and to the Point of Sale (PoS) and storage at both locations (e.g. lighting and heating). Distribution losses of both paint and packaging materials is also included in this stage.

Use stage: This life cycle stage describes the expected use of the final product. In this case it is the transport of the paint to the final customer and its application on the substrates over 50 years. The use of paint trays, brushes, paint rollers, ladder, tape, cloths, and other materials is also included in this study. The disposal of left-over paints, auxiliary materials and accompanying packaging is handled at the End-of-Life stage.

End of life: This is the last stage of the life cycle and starts when the paint products are disposed by the user, and it ends when the product of the study is returned to nature or enters another products' life cycle as recycled input. In this case, end-of-life includes the transportation from final client to waste management sites, the waste treatment of the materials from the use stage, and the disposal of the packaging material. The packaging material is assumed to be incinerated with energy recovery.

4.3.1.2.2 Impact categories

In this study, all EF impact categories defined in the PEF method will be included. The table below shows a list of the impact categories as well as the abbreviations used in this study. In the sections below the investigated system will be described. However, the functional unit and reference flow will be specified in a separate section for each of the investigated decorative paints.

Table 32. PEF impact categories, abbreviations, and units.

Impact category	Abbreviation	Unit
Acidification – EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of NOx, NH3 and SOx lead to releases of hydrogen ions (H+) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.	AP	mol H^+-Eq
Climate change – EF impact category considering all inputs and outputs that result in greenhouse gas (GHG) emissions. The consequences include increased average global temperatures and sudden regional climatic changes. Climate change: fossil Climate change: biogenic Climate change: land use and land use change	CC CC - fossil CC - biogenic CC - LULUC	kg CO2-Eq
Ecotoxicity, freshwater – EF impact category that addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Ecotoxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.	ETox	CTUe
Particulate matter – EF impact category that accounts for the adverse effects on human health caused by emissions of particulate matter (PM) and its precursors (NOx, SOx, NH3).	PM	disease incidence
Eutrophication – EF impact category related to nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland that accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen, resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure, expressed as the oxygen required for the degradation of dead biomass. To assess the impacts due to eutrophication, three EF impact categories are used: eutrophication, terrestrial eutrophication, freshwater; eutrophication marine.	E-Te E-Fr E-Ma	mol N-Eq kg P-Eq kg N-Eq
Human toxicity: carcinogenic - EF impact category that accounts for adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin – insofar as they are related to cancer.	HTox-c	CTUh
Human toxicity: non-carcinogenic - EF impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin – insofar as they are related to non-cancer effects that are not caused by particulate matter/respiratory inorganics or ionising radiation.	HTox-nc	CTUh
Ionising radiation: human health - EF impact category that accounts for the adverse health effects on human health caused by radioactive releases.	IR	kBq U235-Eq
Land use - EF impact category related to use (occupation) and conversion (transformation) of land area by activities such as agriculture, forestry, roads, housing, mining, etc.	LU	dimensionless (pt)
Ozone depletion – EF impact category that accounts for the degradation of stratospheric ozone due to emissions of ozone-depleting substances, for example long-lived chlorine and bromine containing gases (e.g. chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons).	OD	kg CFC-11-Eq
Photochemical ozone formation – EF impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight.	POF	kg NMVOC-Eq

Resource use, fossils – EF impact category that addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).	ER	MJ, net calor. value
Resource use, minerals and metals – EF impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals).	MR	kg Sb-Eq
Water use – EF impact category that represents the relative available water remaining per area in a watershed, after demand from humans and aquatic ecosystems has been met. It assesses the potential for water deprivation, to either humans or ecosystems, based on the assumption that the less water remaining available per area, the more likely it is that another user will be deprived.	WU	m^3 world Eq deprived

Source: Own elaboration based on PEF methodology.

4.3.1.2.3 Normalisation and weighting factors

The PEF methodology allows for impact categories to be normalised and weighted using the factors provided in the table below. These factors allow for a single PEF score to be obtained from the combined impact category results.

Table 33. Normalisation and weighting factors for PEF impact categories.

Impact categories	Abbreviation	Unit	Normalisation factors	Weighting factors
Acidification	AP	mol H^+-Eq	5.56E+01	6.20%
Climate change	CC	kg CO2-Eq	7.55E+03	21.06%
Ecotoxicity, freshwater	ETox	CTUe	5.67E+04	1.92%
Particulate matter	PM	disease incidence	5.95E-04	8.96%
Eutrophication, freshwater	E-Fr	kg P-Eq	1.61E+00	2.80%
Eutrophication, marine	E-Ma	kg N-Eq	1.95E+01	2.96%
Eutrophication, terrestrial	E-Te	mol N-Eq	1.77E+02	3.71%
Human toxicity, cancer	HTox-c	CTUh	1.73E-05	2.13%
Human toxicity, non-cancer	HTox-nc	CTUh	1.29E-04	1.84%
Ionising radiation	IR	kBq U235-Eq	4.22E+03	5.01%
Land use	LU	Dimensionless (pt)	8.19E+05	7.94%
Ozone Depletion	OD	kg CFC-11-Eq	5.23E-02	6.31%
Photochemical ozone formation	POF	kg NMVOC-Eq	4.09E+01	4.78%
Resource depletion, fossil	ER	MJ, net calor. value	6.50E+04	8.32%
Resource depletion, minerals & metals	MR	kg Sb-Eq	6.36E-02	7.55%
Water use	WU	m^3 world Eq deprived	1.15E+04	8.51%

Source: Own elaboration based on the PEF methodology.

4.3.1.3 Life Cycle Inventory (LCI)

Unless specified otherwise, these studies use information from the Environmental Footprint (EF 3.1) datasets for inputs on generic data. Other available datasets such as Ecoinvent were used to attempt to fill any gaps in the EF 3.1 datasets, although there are potential differences in the structure and scope of data provided. A proper comparison of underlying data would not have been possible because the EF datasets were provided without any details of the breakdown of how different sub-processes contributed to the overall result for a given chemical or process.

Some of the most important entries in the EF dataset for chemical ingredients are flagged already in the section on data collection. Later in the EFIA results sections, any specific or proxy EF datasets for packaging and ingredients are mentioned.

4.3.2 EFIA of indoor paint products

The Environmental Footprint Impact Assessment (EFIA) of indoor decorative paints is provided below.

4.3.2.1 Background information and assumptions

Definition of the product: For the purpose of this LCA screening, indoor decorative paints are considered as paints used to cover interior mineral walls and ceilings and fall under the scope of the Paints Directive 2004/42/EC.

Functional unit and reference flows: The functional unit is the protection and decoration of 1 m^2 of indoor substrate for 50 years at a specified quality level (minimum 98% opacity).

The reference flow is the amount of product required to fulfil the functional unit. The amount of indoor paint required to cover 1 m^2 of indoor wall substrate differs depending on the composition of paint, type and colour of substrate, application method, and other factors.

- Coverage (m^2/L): the amount of m^2 one can paint with 1 litre of product with an appropriate contrast ratio.
- Applied paint (fraction): fraction of paint that on average is applied from the can on the wall.
- Paint density (kg/L): the mass (kg) per unit volume (litre).
- Maintenance multiplier (unitless): number of expected maintenance cycles over the reference lifetime of the building (50 years).

The reference flow can be calculated through the equation:

$$\text{kg of paint} = 1\ (m^2) / \text{Coverage}\ (m^2/L) / \text{Applied paint}\ (-) \times \text{Paint density}\ (kg/L) \times \text{Maintenance multiplier}$$

These factors are generally product specific and differ amongst paints and amongst manufacturers. Due to lack of data, the values in the PEFCR for indoor paint are used and are assumed to be representative of a classic indoor paint.

- Coverage: 9.5 m^2/L
- Applied paint: 0.89
- Paint density: 1.43 kg/L
- Maintenance multiplier: 8.33

Therefore, the reference flow for indoor paints is calculated:

$$\text{kg of indoor paint} = 1\ m^2 / 9.50\ m^2/L / 0.89 \times 1.43\ kg/L \times 8.33 = 1.409\ kg$$

The amount of paint for indoor wall required per FU is 1.409 kg.

Formulation

The existing formulations for indoor and outdoor paints and varnishes from the PEFCR for Decorative Paints lack specificity in terms of chemical compounds in the formulas e.g., unspecified additives. Additives are added to change the properties of the paints, depending on the desired characteristics and can take the form of wetting agents, dispersing agents, defoamers, flattening agents, rheology modifiers, driers, accelerators, biocides, and others. As a result, new formulations for both paints and varnishes were researched.

Acrylic latex water-based paints are the most popular type of paint for both interior and exterior, since it dries quicker, is easier to apply and is durable. In addition, it offers better resistance to sunlight exposure. As a result, acrylic water-based indoor paints were chosen for this study.

To find the formulation of an acrylic water-based indoor paint, Prospector® was used. This website from UL combines sources of specialized raw material and ingredient information into one search engine for product developers and engineers[129], including formulations for paints and coatings. It contains formulations from the manufacturers of paints and coatings, which are typically not disclosed publicly.

Prospector® offers many different formulations for acrylic indoor paint, and one formulation for an acrylic interior flat (matte) white paint[130] was chosen, as it seemed to represent well an acrylic water-based indoor paint and each ingredient was listed with its functionality. This formulation has a pigment volume concentration (PVC) of 85 %. The high PVC means high density and hiding capability. However, a high PVC typically causes the performance properties of the paint to decrease, such as durability, and scrub, stain and corrosion resistance[131].

[129] See: Prospector

[130] See: Interior Flat Paint (Formulation #07-1027A) by Ashland

[131] See: PPG Paints: What is pigment volume concentration?

Table 34. Formulation of water-based acrylic indoor paint.

Ingredient	Functionality	kg	% by weight
Water	Vehicle	250.0	25
HEC (hydroxyethylcellulose)	Rheology modifier	4.0	0.4
Sodium polyphospate	Wetting/dispersing agent	2.0	0.2
Sodium polyacrylate	Wetting/dispersing agent	3.0	0.3
Mineral oil	Foam control agent	2.0	0.2
Biocide	In-can preservative	2.0	0.2
Titanium dioxide pigment	Pigment	80.0	8.0
Calcium Carbonate	Extender	190.0	19.0
Calcium Carbonate	Extender	272.0	27.2
Talcum	Extender	20.0	2.0
Styrene acrylic latex	Binder	80.0	8.0
Glycol ether	Coalescing agent	4.0	0.4
Ester alcohol	Coalescing agent	5.0	0.5
Water	Vehicle	86.0	8.6
TOTAL		1000.0	100

Source: Adapted from formulation for Interior Flat Paint (Formulation #07-1027A) by Ashland, found on Prospector®.

Raw material acquisition and preprocessing: The composition of an average indoor paint is based on the formulation above from Prospector® and is shown together with LCI processes from the EF 3.1 database in Table *35*.

Table 35. LCI of a standard formulation of an average indoor paint using the EF 3.1 database. The text highlighted in orange represents chemical compounds that were used as proxies due to the unavailability of ingredient-specific datasets.

Ingredient	%	EF 3.1 process
Water	25 + 8.6	Tap water {EU+EFTA+UK} | average technology mix | consumption mix, at consumer | Technology mix for supply of drinking water to users | LCI result
HEC (hydroxyethylcellulose)	0.4	Proxy: Carboxymethyl cellulose production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Sodium polyphosphate	0.2	Sodium phosphate production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Sodium polyacrylate	0.3	Polyacrylates in water solution production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Mineral oil	0.2	Proxy: Hydro-carbon oils {EU+EFTA+UK} | LCI result
Biocide	0.2	Proxy: Benzimidazole-compound production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result
Titanium dioxide pigment	8.0	Titanium dioxide production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Calcium Carbonate	19.0 + 27.2	Calcium carbonate production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Talcum	2.0	Talcum powder {EU+EFTA+UK} | grinded and purified, filler, production including underground mining and beneficiation | production mix, at plant | 1 to 15 microns grain size | LCI result
Styrene acrylic latex	8.0	Acrylic binder production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Glycol ether	0.4	Proxy: Dipropylene glycol monomethyl ether production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result

Ingredient	%	EF 3.1 process
Ester alcohol	0.5	Proxy: Glycerol esters (glycerol monostearate, GMS) ethoxylated amines {GLO} | production mix, at plant | Glycerol esters for use within polymers prior to yarn spinning. | LCI result

Source: Own elaboration.

The EF 3.1 database lacks some of the chemical compounds in the formulation. For this reason, other chemical compounds were chosen as proxies, based on similarity and functionality. Proxies for hydroxyethylcellulose, sodium polyacrylate, glycol ether, and ester alcohol were chosen. Research was conducted for regular mineral oils and biocides used in paints and based on it, compounds from the EF 3.1 database were chosen.

Primary, secondary, and tertiary packaging is included in this phase of the life cycle. The composition is also derived from the Decorative Paints PEFCR v1.0 – Life Cycle Inventory and is shown in Table *36* together with the LCI processes used in the study.

In addition, the transport of the raw materials and packaging are included in this stage. According to the PEFCR, the raw materials are transported 460 km to the production location, whereas the packaging materials are transported 250 km. The transportation takes place by truck and a utilization rate of 64% is used, according to the PEFCR.

Table 36. LCI of both primary, secondary and tertiary packaging for indoor wall paint.

Type of packaging	Amount	EF 3.1 process
Primary (sales packaging):	Per FU	
Steel can	0.0085 kg	Steel tinplated {EU+EFTA+UK} | blast furnace route | single route, at plant | 1kg, typical thickness between 0.13 - 0.49 mm. typical width between 600 - 1100 mm. | LCI result
PP parts	0.0439 kg	PP granulates {EU+EFTA+UK} | polymerisation of propene | production mix, at plant | 0.91 g/cm3, 42.08 g/mol per repeating unit | LCI result
	0.0418 kg	Polypropylene (PP) fibers {EU+EFTA+UK} | polypropylene production, spinning | production mix, at plant | 5% loss, 3.5 MJ electricity | Partly terminated system
Secondary (grouped packaging):	Per FU	
Cardboard	0.0010 kg	Corrugated box, uncoated {EU+EFTA+UK} | Kraft Pulping Process, pulp pressing and drying | production mix, at plant | 280 g/m2, R1=88% | LCI result
Tertiary (transport packaging):	Per FU	
PE film	0.0011 kg	Plastic, stretch film {EU+EFTA+UK} | raw material production, plastic extrusion | production mix, at plant | thickness: 30 um, grammage: 0,02754 kg/m2 | LCI result
Wooden pallet	0.0557 kg	Pallet, wood (80x120) {EU+EFTA+UK} | sawing, piling, nailing | single route, at plant | 25 kg/piece, nominal loading capacity of 1000kg | LCI result

Source: Own elaboration.

Manufacturing: In the manufacturing stage, the use of electricity, water, heat, and output of wastewater has been included. The data for electricity, heat, light fuel oil, and water usage are based on the PEFCR for decorative paints. According to the PEFCR, there are 3% paint losses during the manufacturing stage, which have been included in this study.

Distribution: The distribution stage includes the transport of the paint from the factory to the Regional Distribution Centre (RDC) and to the Point of Sale (PoS). According to the PEFCR, the package paint is transported 350 km by truck to the RDC and 370 km to the PoS. In addition, a total utilization rate of the trucks is 64%.

Furthermore, as defined by section 4.4.5 of the PEF Recommendation, both lighting and heating of storage in distribution centre and retail has been included and the data is taken from the PEFCR LCI for Decorative Paints. To account for losses during distribution, a 1% loss of paint at the RDC and a 1% loss of paint and packaging at PoS have been included according to PEFCR.

Use: In the use stage, the application of paint requires auxiliary materials, which are included in this study. Losses during application are also accounted for and according to the PEFCR, 89% of the paint (application factor) is applied and the remaining 11% is lost and treated as non-hazardous waste at the end-of-life stage.

End-of-life: The end-of-life stage consists of the transport of waste, incineration with energy recovery and landfilling. Each waste material is transported 80 km to its end-of-life treatment, with a truck utilization rate of 64%.

The end-of-life in this case covers the disposal of the substrate with indoor paint in a landfill. It also includes the waste treatment of paint leftovers, auxiliary materials, and packaging from the use stage. Waste leftovers and auxiliary materials are disposed of as hazardous and non-hazardous waste, respectively, 45% of which is incinerated and 55% of which is landfilled, according to the PEFCR. Finally, packaging is assumed to be incinerated with energy recovery.

Data quality: The assessment of the data quality is split up into the different life cycle stages; raw material acquisition and pre-processing (LCS1), manufacturing (LCS2), distribution stage (LCS3), use stage (LCS4), and End of Life (LCS5).

- LCS1: Data quality regarding the average composition of indoor paint is fair. Although formulation data from manufacturers for an average indoor paint was unavailable, the ingredient data for an acrylic water-based indoor paint collected from 2015 is deemed representative of an indoor paint today. For some ingredients, no LCI data was available in the EF 3.1 database and here proxies were used. The data quality for packaging is good and was collected from the PEFCR's LCI for decorative paints.
- LCS2: The data quality of the manufacturing process was retrieved from the PEFCR's LCI and is deemed good. The datasets used from the EF 3.1 database for electricity, light fuel oil, natural gas, water and wastewater treatment are good.
- LCS3: Data regarding the distribution stage was also retrieved from the PEFCR's LCI. The quality of the LCI data and the datasets used is good.
- LCS4: The data inputs are retrieved from the PEFCR's LCI and data quality of this stage is good. For some materials, no LCI data was available in the EF 3.1 database and ecoinvent datasets were used.
- LCS5: The data in the End-of-Life stage is based on the PEFCR's LCI and accounts for the disposal of waste through landfill or incineration. However, the LCI does not account for recycling of materials. The overall data quality of this life cycle stage is fair.

The data used in this study represents average indoor paints. Hence, the results do not address the environmental performance of individual products. No data was found on the factors affecting the reference flow (coverage, paint density, maintenance multiplier) for the specific formulation used. As a result, the reference flow was based on the factors provided in the PEFCR.

4.3.2.2 Life cycle impact assessment (LCIA) for indoor paints: results and interpretation

4.3.2.2.1 Contribution analysis for indoor paint products

A contribution analysis was made to identify hotspots in the life cycle stages of indoor paints, the results are presented below in Table *37*.

Table 37. Characterised, normalised and weighted impacts of indoor paints.

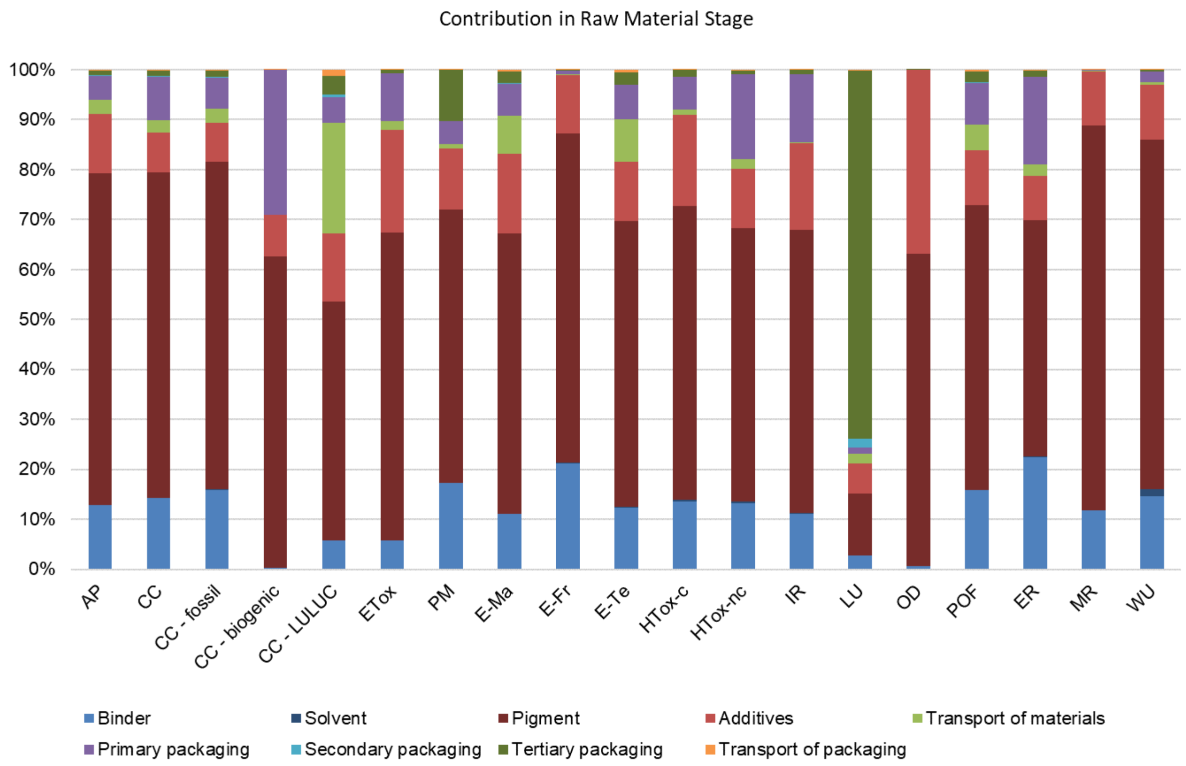
Impact category	Characterised impact						Normalised impact	Weighted impact
	Raw material acquisition	Manufacturing	Distribution	Use	End-of-Life	Total		
Acidification [mol of H^+ eq]	7.19E-03	6.56E-04	7.55E-04	4.17E-03	3.57E-04	1.31E-02	2.36E-04	1.46E-05
Climate Change [kg CO_2 eq]	1.34E+00	2.49E-01	2.31E-01	1.28E+00	1.61E+00	4.71E+00	6.24E-04	1.31E-04
Climate Change (fossil) [kg CO_2 eq]	1.20E+00	2.29E-01	2.17E-01	1.27E+00	3.12E-01	3.22E+00	-	-
Climate Change (biogenic) [kg CO_2 eq]	1.46E-01	2.02E-02	1.36E-02	4.97E-03	1.30E+00	1.49E+00	-	-
Climate Change (land use and land use change) [kg CO_2 eq]	1.07E-03	3.25E-05	7.37E-04	4.31E-03	2.56E-04	6.41E-03	-	-
Ecotoxicity – freshwater [CTUe]	1.92E+01	8.25E-01	1.06E+00	1.58E+01	1.57E+00	3.85E+01	6.78E-04	1.30E-05
Particulate matter [Disease incidence]	9.56E-08	6.43E-09	3.68E-09	3.53E-08	2.07E-09	1.43E-07	2.40E-04	2.15E-05
Eutrophication – marine [kg N eq]	1.29E-03	1.26E-04	3.32E-04	1.40E-03	5.38E-04	3.68E-03	1.88E-04	5.28E-06
Eutrophication – freshwater [kg P eq]	9.68E-05	6.93E-07	1.06E-06	1.13E-05	3.91E-05	1.49E-04	9.27E-05	2.74E-06
Eutrophication – terrestrial [mol N eq]	1.28E-02	1.31E-03	3.66E-03	1.70E-02	2.82E-03	3.75E-02	2.12E-04	7.87E-06
Human toxicity – cancer [CTUh]	7.58E-10	3.25E-11	3.53E-11	5.02E-10	5.47E-11	1.38E-09	8.01E-05	1.71E-06
Human toxicity – non-cancer [CTUh]	1.15E-08	9.17E-10	9.07E-10	6.01E-09	6.37E-09	2.57E-08	2.00E-04	3.68E-06
Ionising Radiation [kBq U^{235} eq]	8.47E-02	7.79E-02	8.00E-03	1.81E-02	-5.08E-02	1.38E-01	3.27E-05	1.64E-06
Land Use [Pt]	1.43E+01	2.93E-01	8.57E-01	3.99E+00	1.13E-01	1.95E+01	2.38E-05	1.89E-06
Ozone Depletion [kg CFC-11 eq]	3.36E-08	6.02E-11	5.18E-12	9.31E-11	-4.08E-11	3.37E-08	6.43E-07	4.06E-08
Photochemical Ozone Formation [kg NMVOC eq]	3.67E-03	3.90E-04	6.98E-04	3.38E-03	1.23E-03	9.37E-03	2.29E-04	1.10E-05
Resource depletion – fossils [MJ]	2.07E+01	5.71E+00	3.13E+00	1.75E+01	-1.77E+00	4.53E+01	6.97E-04	5.80E-05
Resource depletion – minerals and metals [kg Sb eq]	9.49E-06	3.46E-08	4.91E-08	7.01E-06	1.07E-07	1.67E-05	2.62E-04	1.98E-05
Water use [m^3 world eq]	6.33E-01	3.74E-02	9.60E-03	1.32E-01	-2.46E-01	5.66E-01	4.94E-05	4.20E-06

Source: Own elaboration.

Generally, the most contributing life cycle stage to the impact of covering 1 m^2 of indoor substrate for 50 years with a minimum 98% opacity is the raw material stage, followed by the use and End-of-Life stages. The negative impacts (i.e. environmental benefits) in impact categories IR, OD, ER and WU are due to the incineration with energy recovery of materials during the EoL stage. The impacts related to the EoL stage primarily stem from the waste treatment of materials, particularly the waste treatment of dried paint, which is landfilled. On the other hand, the impacts in the use stage stem primarily from the application of paint on the substrate.

The raw material stage consists of many sub-processes. The contribution of these sub-processes to the total impact of the raw material and preprocessing stage is evaluated in Figure 26.

Figure 26. Characterised results for indoor paints life cycle stages, presented in percentage of total impact, split by life cycle stage for each of the impact categories.



Source: Own elaboration based on LCIA results.

Despite only accounting for 8% of the total indoor paint ingredients, the pigment, in this case the production of titanium dioxide, is the biggest contributor to 18 out of 19 impact categories within the raw material life cycle stage. It includes all categories, except LU, for which tertiary packaging contributes 74% of LU impacts, due to the production of wooden pallets.

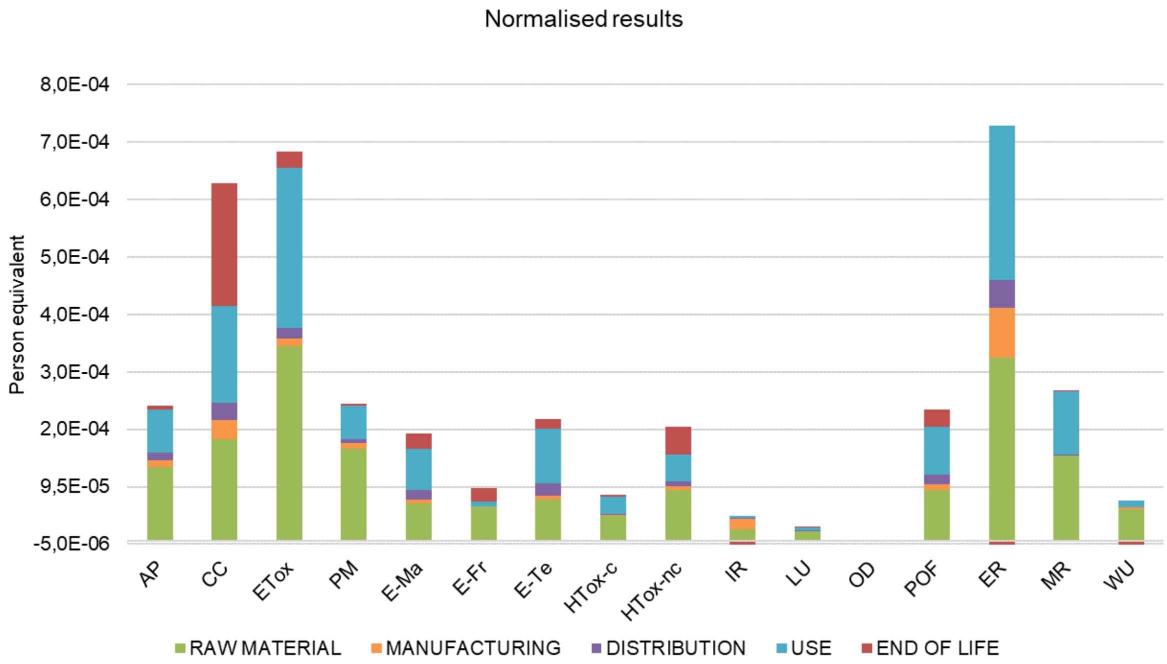
Binder production has a similar impact to additives production, although it makes up only 8% of the total ingredients in indoor paint, whereas additives make up more than 50% of the ingredients.

Finally, although the solvent accounts for more than 33% of the ingredients, its impact across categories is insignificant. These results are expected since the solvent used is water.

4.3.2.2.2 Normalised results for indoor paint products

The characterised results presented above are normalised using the EF 3.1 normalisation factors, which can be found in section 4.3.1.2.3. Figure *27* shows the normalised results within all impact categories split by life cycle stages.

Figure 27. Normalised results of an average indoor paint presented in Person Equivalent (using EF 3.1 normalisation factors) for different impact categories.



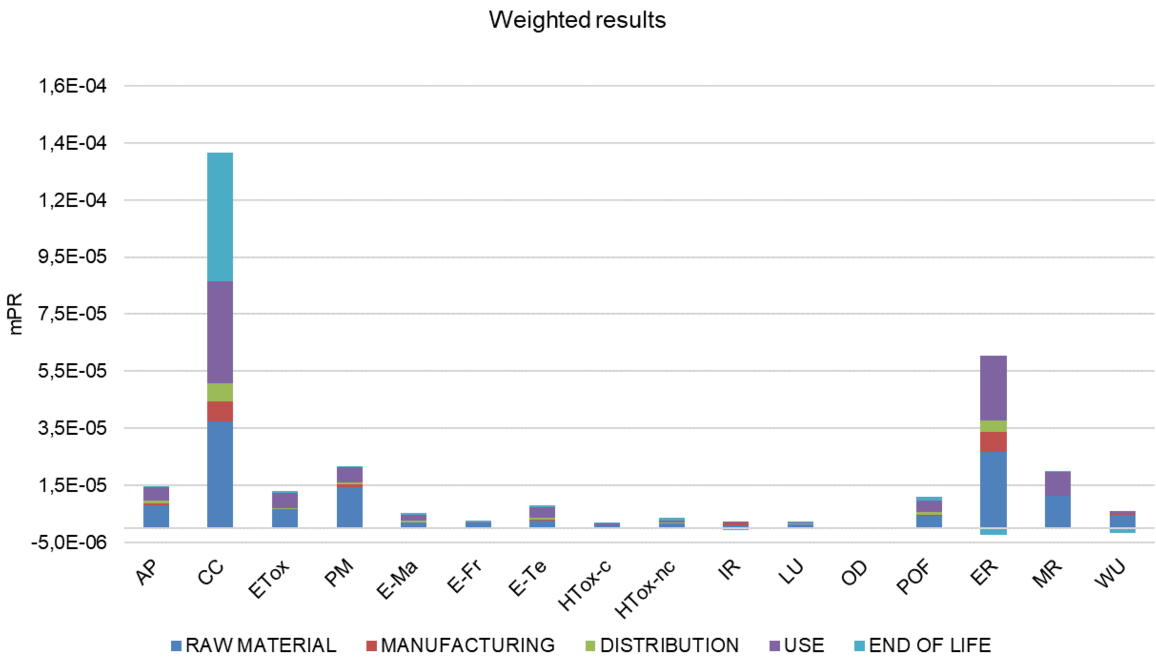
Source: Own elaboration based on LCIA results.

The highest impacts are seen for CC, ETox and ER. The raw material stage has the highest contribution to all three impact categories, followed by the EoL stage for CC and the use stage for the remaining two categories. The lowest normalised impacts are seen for OD and LU.

4.3.2.2.3 Weighted results for indoor paint products

Weighting the LCA results is a mandatory step in the PEF methodology. During weighting, the normalised results are multiplied by weighting factors reflecting the importance of the different life cycle impact categories. The weighting factors can be found in section 4.3.1.2.3.

Figure 28. Weighted results of an average indoor paint presented in Person Equivalent (using EF 3.1 normalisation factors) for different impact categories.



Source: Own elaboration based on LCIA results.

Figure *28* shows the contribution of each life cycle stage to different impact categories. According to the results, the highest impacts are seen for CC and ER, whereas the lowest are seen for OD, LU, HTox-c, and E-Fr.

Table *38* shows the sum of weighted results per life cycle stage. The weighted results are aggregated across all impact categories obtaining an overall score for each life cycle stage. The results show that the raw material stage accounts for 41.7% of impacts, followed by the use stage with 31.7%. The distribution stage has the lowest contribution, with only 4.9%.

Table 38. Weighted results using the EF 3.1 weighting factors provided by the European Commission.

Life cycle stage	Value	Unit	% share
Raw material	1.24E-04	mPR	41.7%
Manufacturing	1.86E-05	mPR	6.2%
Distribution	1.48E-05	mPR	4.9%
Use	9.45E-05	mPR	31.7%
End-of-life	4.61E-05	mPR	15.5%
TOTAL	2.98E-04	mPR	100%

Source: Own elaboration.

4.3.2.2.4 Interpretation of EFIA results for indoor paint products

The most relevant impact category, lifecycle stages (LCS), and processes are identified and presented in Table *39*. The contribution of each impact category and LCS is based on the normalised and weighted impacts. In contrast, the most relevant processes are based on the characterised results of the LCA. The contributions are presented in absolute values as suggested by the PEF method.

Table 39. Overview of the most relevant impact categories, lifecycle stages, and processes of indoor paint products.

Most relevant impact category	%	Most relevant LCS	%	Most relevant processes	%
Climate change	43%	LCS1	28%	TiO2	19%
				Styrene acrylic latex	4%
		LCS4	27%	Application	27%
		LCS5	34%	EoL dried paint	30%
				Manufacturing	5%
Energy resources: non-renewable	20%	LCS1	42%	TiO2	20%
				Styrene acrylic latex	9%
				Packaging primary	7%
		LCS2	12%	Paint manufacturing	12%
		LCS4	36%	Application	35%
Particulate matter formation	7%	LCS1	67%	TiO2	36%
				Styrene acrylic latex	11%
				Packaging tertiary	7%
		LCS4	25%	Application	23%
				Manufacturing	4%
Material resources: metals/minerals	6%	LCS1	57%	TiO2	44%
		LCS4	42%	Application	42%
Acidification	5%	LCS1	55%	TiO2	36%
				Styrene acrylic latex	7%
		LCS4	32%	Application	31%
				Manufacturing	5%
				Distribution PoS	3%

Source: Own elaboration.

The most relevant impact categories are by the PEF method defined as those that together account for at least 80% of the single overall PEF score. The most relevant impact category for indoor paint products is Climate change accounting for 43% of the total impact, followed by Energy resources: non-renewable (20%), Particulate matter formation (7%), Material resources: metals/minerals (6%), and Acidification (5%).

The most relevant LCS are in the PEF method defined as those stages that account for more than 80% to the specific impact category. LCS1 – raw material acquisition and pre-processing is the most relevant LCS within 4 out of 5 most relevant impact categories, contributing between 42% and 67%. The exception is Climate change, where LCS5 – End of life is the most relevant LCS. In general, LCS1 and LCS4 (Use stage) are always present as most relevant LCS. Hence special attention should be given to these LCS and be borne in mind, when making new EU Ecolabel criteria.

The most relevant processes are defined as all processes that together contribute more than 80% to the specific impact category. In the case of most relevant processes, one looks at the contribution along the entire life cycle. Titanium dioxide is the most relevant process within all the most relevant impact categories. Accounting for between 19% (climate change) and 44% (Material resources: metals/minerals). Hence, Titanium dioxide has a large influence on the total environmental impact of the pigmented paints when used, and alternative pigments will be further investigated in section 4.5.1. It should be noted also, that while TiO_2 is widely used as a pigment, it is also an expensive raw material, and in many paints, producers will therefore seek to also add other, cheaper pigments or extenders to decrease the amount of TiO_2 needed, as is also the case for the formulation used for this LCA screening (in table 4), where calcium carbonate is used as extender.

Another process that appears as a most relevant process within all impact categories is the application process (between 23% for Particulate matter formation and 42% for material resources metals/minerals). The impact within the application is mainly related to the transport of the paint, which includes going to the shop, meetings with professional painters, selecting and getting the materials as described in the PEFCR for decorative paints. Lastly, the end of life of the dried paint is a relevant process within Climate change, which is send to landfill.

4.3.2.2.5 Summary of EFIA of indoor paint

Conducting the EFIA study revealed the following conclusions:

- The raw material acquisition and preprocessing stage is the most contributing life cycle stage when assessing the environmental performance of covering one square meter of substrate with indoor paint for 50 years. Most of impacts during this stage are related to pigment (titanium dioxide) production.
- The use stage is the second most impactful stage, of which the application of paint on the substrate has a particular high impact.
- The highest normalised impacts are seen within ER, ETox and CC categories.
- The weighted results revealed the raw material stage to account for approx. 42% of the environmental impacts of indoor paint, followed by the use stage with approx. 32%.

4.3.3 EFIA of outdoor paint products

The Environmental Footprint Impact Assessment (EFIA) of outdoor wall paints is provided below.

4.3.3.1 Background information and assumptions

Definition of the product: For the purpose of this LCA screening, outdoor decorative paints are considered as paints used to cover outdoor mineral substrate and fall under the scope of the Paints Directive 2004/42/EC.

Functional unit and reference flows: The functional unit (FU) is the protection and decoration of 1 m^2 of outdoor wall substrate for 50 years at a specified quality level (minimum 98% opacity).

The amount of outdoor paint required to cover 1 m^2 of outdoor wall substrate differs depending on the composition of paint, type and colour of substrate, application method, and other factors.

These factors are generally product specific and differ amongst paints and amongst manufacturers. Due to lack of data, the values in the PEFCR for outdoor wall paint are used and are assumed to be representative of a classic outdoor paint.

- Coverage: 7 m^2/L
- Applied paint: 0.89
- Paint density: 1.30 kg/L
- Maintenance multiplier: 5

Therefore, the reference flow for outdoor paints is calculated:

$$\text{kg of indoor paint} = 1\ m^2 / 7\ m^2/L / 0.89 \times 1.30\ kg/L \times 5 = 1.043\ kg$$

The amount of paint for outdoor wall required per FU is 1.043 kg.

Formulation

Both indoor and outdoor acrylic paints are similar, yet they have different purposes and thereby differ in terms of formulations. The purpose of outdoor paint is to protect the surface it covers from UV radiation and different weather conditions. Therefore, outdoor paint is formulated differently so that it can endure the outdoor elements. Nevertheless, a water-based acrylic outdoor paint is chosen due to its popularity.

Although Prospector® also provided formulations for many types of outdoor paints, most referred to both interior and exterior paints. As these paints have different purposes and therefore should have different formulations, other literary sources were searched specifically for outdoor paints and the formulation for one type of acrylic waterborne paint was found[132].

[132] Hebah Abdel-Wahab (2022) Acrylic Matt and Gloss Paints. J. Pharmaceutics and Pharmacology Research. 5(8); DOI: 10.31579/2693-7247/097

Table 40. Formulation of acrylic water-based outdoor paint.

Ingredient	Functionality	% by weight
Water	Solvent	44.09
Hydroxyethylcellulose	Nonionic water thickener	0.4
Sodium bicarbonate	Pigment	0.14
Polyoxyethylene (25) octyl phenyl ether	Surfactant and buffer	2.0
Octyl phenol polyglycol ether sulfate sodium salt	Surfactant and buffer	2.0
Sodium vinylsulfonate	Surfactant	0.5
Butyl acrylate	Monomer in homo or copolymerisation (binder)	2.0
Vinyl acetate	Monomer in homo or copolymerisation (binder)	47.0
Potassium Persulfate	Initiator	0.1258
Tertiary butyl hydrogen peroxide	Oxidizing catalyst	0.0234
Hydrogen peroxide	Initiator	0.06
Sodium formaldehyde sulfoxylate	Reducing agent	0.05
Dibutyl phthalate	Secondary plasticiser	1.0
Formaline	Preservative	0.1
Biocide	Biocide	0.05
Vinyltrimethoxysilane	Crosslinking polymer	0.1
Defoamer	Defoamer	0.06
TOTAL		100

Source: Adapted from Hebah Abdel-Wahab (2022) Acrylic Matt and Gloss Paints. J. Pharmaceutics and Pharmacology Research. 5(8).

Raw material acquisition and preprocessing: The composition of an average outdoor paint is based on the formulation above from Abdel-Wahab (2022) and is shown together with LCI processes from the EF 3.1 database in Table 41.

Table 41. LCI of a standard formulation of an average outdoor wall paint using the EF 3.1 database. The text highlighted in orange represents chemical compounds that were used as proxies due to the unavailability of ingredient-specific datasets.

Ingredient	%	EF 3.1 process
Water	44.09	Tap water {EU+EFTA+UK} | average technology mix | consumption mix, at consumer | Technology mix for supply of drinking water to users | LCI result
Hydroxyethylcellulose	0.4	Proxy: Carboxymethyl cellulose production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Sodium bicarbonate	0.14	Sodium bicarbonate production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Polyoxyethylene (25) octyl phenyl ether	2.0	Proxy: Non-ionic surfactant, ethyleneoxidederivate production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result
Octyl phenol polyglycol ether sulfate sodium salt	2.0	Proxy: Sodium sulphate production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Sodium vinylsulfonate	0.5	Proxy: Sodium cumenesulphonate production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Butyl acrylate	2.0	Butyl acrylate production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Vinyl acetate	47.0	Vinyl acetate {GLO} | production mix, at plant | Vinyl acetate for use within footwear manufacture | LCI result

Ingredient	%	EF 3.1 process
Potassium Persulfate	0.1258	Potassium sulphate production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Tertiary butyl hydrogen peroxide	0.0234	Proxy: 2,5-Bis(tert-butylperoxy)-2,5-dimethylhexane production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result
Hydrogen peroxide	0.06	Hydrogen peroxide, 100% production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Sodium formaldehyde sulfoxylate	0.05	Proxy: Sodium hydrogen sulphite production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Dibutyl phthalate	1.0	Proxy: Dioctyl terephthalate (DOTP) {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result
Formaline	0.1	Proxy: Formaldehyde production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
Biocide	0.05	Proxy: Benzimidazole-compound production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result
Vinyltrimethoxysilane	0.1	Proxy: Silicone, high viscosity {EU+EFTA+UK} | hydrolysis and methanolysis of dimethyldichloro silane | production mix, at plant | >30 000 centi Poise | LCI result
Defoamer	0.06	Antifoaming agent, silicone emulsion production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result

Source: Own elaboration.

The EF 3.1 database lacks some of the chemical compounds in the formulation. For this reason, other chemical compounds were chosen as proxies, based on similarity and functionality. Proxies for hydroxyethylcellulose, polyoxyethylene (25) octyl phenyl ether, octyl phenol polyglycol ether sulfate sodium salt, sodium vinylsulfonate, tertiary butyl hydrogen peroxide, sodium formaldehyde sulfoxylate, dibutyl phthalate, formaline and vinyltrimethoxysilane were chosen based on chemical similarity. Research was conducted for regular biocides used in paints and based on it, compounds from the EF 3.1 database were chosen.

Primary, secondary, and tertiary packaging is included in this phase of the life cycle. The composition is also derived from the PEFCR LCI for Decorative Paints and is shown in Table *42* together with the LCI processes used in the study.

In addition, the transport of the raw materials and packaging are included in this stage. According to the PEFCR, the raw materials are transported 460 km to the production location, whereas the packaging materials are transported 250 km. The transportation takes place by truck and a utilization rate of 64% is used, according to the PEFCR.

Table 42. LCI of both primary, secondary, and tertiary packaging for outdoor wall paint.

Type of packaging	Amount	EF 3.1 process
Primary (sales packaging):	Per FU	
Steel can	0.0063 kg	Steel tinplated {EU+EFTA+UK} | blast furnace route | single route, at plant | 1kg, typical thickness between 0.13 - 0.49 mm. typical width between 600 - 1100 mm. | LCI result
PP parts	0.0325 kg	PP granulates {EU+EFTA+UK} | polymerisation of propene | production mix, at plant | 0.91 g/cm3, 42.08 g/mol per repeating unit | LCI result
	0.0310 kg	Polypropylene (PP) fibers {EU+EFTA+UK} | polypropylene production, spinning | production mix, at plant | 5% loss, 3.5 MJ electricity | Partly terminated system
Secondary (grouped packaging):	Per FU	
Cardboard	0.0007 kg	Corrugated box, uncoated {EU+EFTA+UK} | Kraft Pulping Process, pulp pressing and drying | production mix, at plant | 280 g/m2, R1=88% | LCI result

Type of packaging	Amount	EF 3.1 process
Tertiary (transport packaging):	Per FU	
PE film	0.0008 kg	Plastic, stretch film {EU+EFTA+UK} | raw material production, plastic extrusion | production mix, at plant | thickness: 30 um, grammage: 0,02754 kg/m2 | LCI result
Wooden pallet	0.0412 kg	Pallet, wood (80x120) {EU+EFTA+UK} | sawing, piling, nailing | single route, at plant | 25 kg/piece, nominal loading capacity of 1000kg | LCI result

Source: Own elaboration.

Manufacturing: In the manufacturing stage, the use of electricity, water, heat, and output of wastewater has been included. The data for electricity, heat, light fuel oil, and water usage are based on the PEFCR for decorative paints. According to the PEFCR, there are 3% paint losses during the manufacturing stage, which have been included in this study.

Distribution: The distribution stage includes the transport of the paint from the factory to the Regional Distribution Centre (RDC) and to the Point of Sale (PoS). According to the PEFCR, the package paint is transported 350 km by truck to the RDC and 370 km to the PoS. In addition, a total utilization rate of the trucks is 64%. Furthermore, as defined by section 4.4.5 of the PEF Recommendation, both lighting and heating of storage in distribution centre and retail has been included and the data is taken from the PEFCR LCI for Decorative Paints. To account for losses during distribution, a 1% loss of paint at the RDC and a 1% loss of paint and packaging at PoS have been included according to PEFCR.

Use: In the use stage, the application of paint requires auxiliary materials, which are included in this study. Losses during application are also accounted for and according to the PEFCR, 89% of the paint (application factor) is applied and the remaining 11% is lost and treated as non-hazardous waste at the end-of-life stage.

End-of-life: The end-of-life stage consists of the transport of waste, incineration with energy recovery and landfilling. Each waste material is transported 80 km to its end-of-life treatment, with a truck utilization rate of 64%.

The end-of-life in this case covers the final disposal of the substrate with indoor paint in a landfill. It also includes the waste treatment of hazardous and non-hazardous waste generated during manufacturing and use, 45% of which is incinerated and 55% of which is landfilled, according to the PEFCR. Finally, packaging is assumed to be incinerated with energy recovery.

Data quality: The assessment of the data quality is split up into the different life cycle stages; raw material acquisition and pre-processing (LCS1), manufacturing (LCS2), distribution stage (LCS3), use stage (LCS4), and End of Life (LCS5).

- LCS1: Data quality regarding the average composition of outdoor paint is fair. Although formulation data from manufacturers for an average outdoor paint was unavailable, the ingredient data for an acrylic water-based outdoor paint collected from 2022 is deemed representative of an outdoor paint today. For some ingredients, no LCI data was available in the EF 3.1 database and here proxies were used. The data quality for packaging is good and was collected from the PEFCR's LCI for decorative paints.
- LCS2: The data quality of the manufacturing process was retrieved from the PEFCR's LCI and is deemed good. The datasets used from the EF 3.1 database for electricity, light fuel oil, natural gas, water and wastewater treatment are good.
- LCS3: Data regarding the distribution stage was also retrieved from the PEFCR's LCI. The quality of the LCI data and the datasets used is good.
- LCS4: The data inputs are retrieved from the PEFCR's LCI and data quality of this stage is good. For some materials, no LCI data was available in the EF 3.1 database and ecoinvent datasets were used.
- LCS5: The data in the End-of-Life stage is based on the PEFCR's LCI and accounts for the disposal of waste through landfill or incineration. However, the LCI does not account for recycling of materials. The overall data quality of this life cycle stage is fair.

The data used in this study represents average outdoor paints. Hence, the results do not address the environmental performance of individual products. No data was found on the factors affecting the reference flow (coverage, paint density, maintenance multiplier) for the specific formulation used. As a result, the reference flow was based on the factors provided in the PEFCR.

4.3.3.2 Life cycle impact assessment (LCIA) for outdoor paints: results and interpretation

4.3.3.2.1 Contribution analysis for outdoor paint products

A contribution analysis was made to identify hotspots in the life cycle stages of outdoor paints, the results are presented below in Table *43*.

Table 43. Characterised, normalised and weighted impacts of outdoor paints.

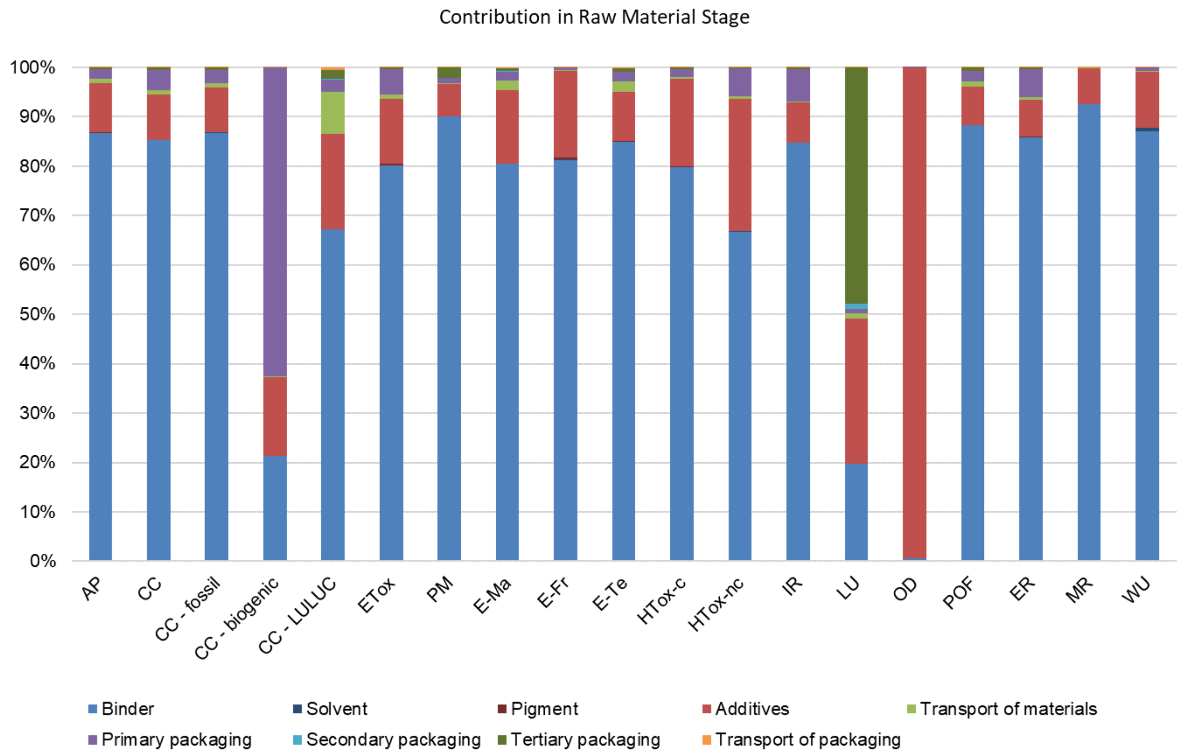
Impact category	Characterised impact						Normalised impact	Weighted impact
	Raw material acquisition	Manufacturing	Distribution	Use	End-of-Life	Total		
Acidification [mol of H^+ eq]	1.41E-02	4.86E-04	5.59E-04	2.53E-03	2.65E-04	1.79E-02	3.22E-04	2.00E-05
Climate Change [kg CO_2 eq]	2.20E+00	1.84E-01	1.71E-01	7.75E-01	1.19E+00	4.52E+00	5.98E-04	1.26E-04
Climate Change (fossil) [kg CO_2 eq]	2.14E+00	1.69E-01	1.60E-01	7.68E-01	2.31E-01	3.47E+00	-	-
Climate Change (biogenic) [kg CO_2 eq]	5.01E-02	1.49E-02	1.01E-02	4.05E-03	9.63E-01	1.04E+00	-	-
Climate Change (land use and land use change) [kg CO_2 eq]	1.73E-03	2.41E-05	5.46E-04	2.60E-03	1.90E-04	5.08E-03	-	-
Ecotoxicity – freshwater [CTUe]	2.64E+01	6.11E-01	7.82E-01	9.56E+00	1.16E+00	3.85E+01	6.79E-04	1.30E-05
Particulate matter [Disease incidence]	3.32E-07	4.76E-09	2.72E-09	2.17E-08	1.53E-09	3.62E-07	6.09E-04	5.46E-05
Eutrophication – marine [kg N eq]	3.26E-03	9.33E-05	2.46E-04	8.46E-04	3.98E-04	4.84E-03	2.48E-04	6.93E-06
Eutrophication – freshwater [kg P eq]	9.95E-05	5.13E-07	7.87E-07	7.50E-06	2.90E-05	1.37E-04	8.54E-05	2.53E-06
Eutrophication – terrestrial [mol N eq]	3.25E-02	9.71E-04	2.71E-03	1.02E-02	2.09E-03	4.85E-02	2.74E-04	1.02E-05
Human toxicity – cancer [CTUh]	2.19E-09	2.41E-11	2.61E-11	3.22E-10	4.05E-11	2.60E-09	1.51E-04	3.21E-06
Human toxicity – non-cancer [CTUh]	2.58E-08	6.79E-10	6.72E-10	3.82E-09	4.71E-09	3.57E-08	2.77E-04	5.11E-06
Ionising Radiation [kBq U^{235} eq]	1.31E-01	5.76E-02	5.92E-03	1.16E-02	-3.76E-02	1.69E-01	3.99E-05	2.00E-06
Land Use [Pt]	1.63E+01	2.17E-01	6.34E-01	2.53E+00	8.33E-02	1.98E+01	2.41E-05	1.91E-06
Ozone Depletion [kg CFC-11 eq]	8.44E-07	4.45E-11	3.84E-12	1.17E-10	-3.02E-11	8.44E-07	1.61E-05	1.02E-06
Photochemical Ozone Formation [kg NMVOC eq]	1.04E-02	2.89E-04	5.17E-04	2.05E-03	9.10E-04	1.42E-02	3.46E-04	1.66E-05
Resource depletion – fossils [MJ]	4.89E+01	4.23E+00	2.32E+00	1.07E+01	-1.31E+00	6.47E+01	9.96E-04	8.29E-05
Resource depletion – minerals and metals [kg Sb eq]	2.02E-05	2.56E-08	3.64E-08	4.23E-06	7.94E-08	2.46E-05	3.87E-04	2.92E-05
Water use [m^3 world eq]	1.48E+00	2.77E-02	7.10E-03	1.21E-01	-1.82E-01	1.45E+00	1.26E-04	1.08E-05

Source: Own elaboration.

Generally, the most contributing life cycle stage to the impact of covering 1 m^2 of outdoor substrate for 50 years with a minimum 98% opacity is the raw material stage, followed by the use and End-of-Life stages. The negative impacts (i.e. environmental benefits) in impact categories IR, OD, ER and WU are due to the incineration with energy recovery of materials during the EoL stage. The impacts related to the EoL stage primarily stem from the waste treatment of materials, particularly the waste treatment of dried paint, which is landfilled. The impacts in the use stage stem primarily from the application of paint on the substrate.

The raw material stage consists of many sub-processes. The contribution of these sub-processes to the total impact of the raw material and preprocessing stage is evaluated in Figure *29*.

Figure 29. Characterised results for indoor paints life cycle stages, presented in percentage of total impact, split by life cycle stage for each of the impact categories.



Source: Own elaboration based on LCIA results.

Binder production is the biggest contributor to 16 out of 19 impact categories within the raw material life cycle stage. For this outdoor paint, two different types of binders were used: butyl acrylate (2%) and vinyl acetate (47%). However, most of the impacts can be attributed to the production of vinyl acetate.

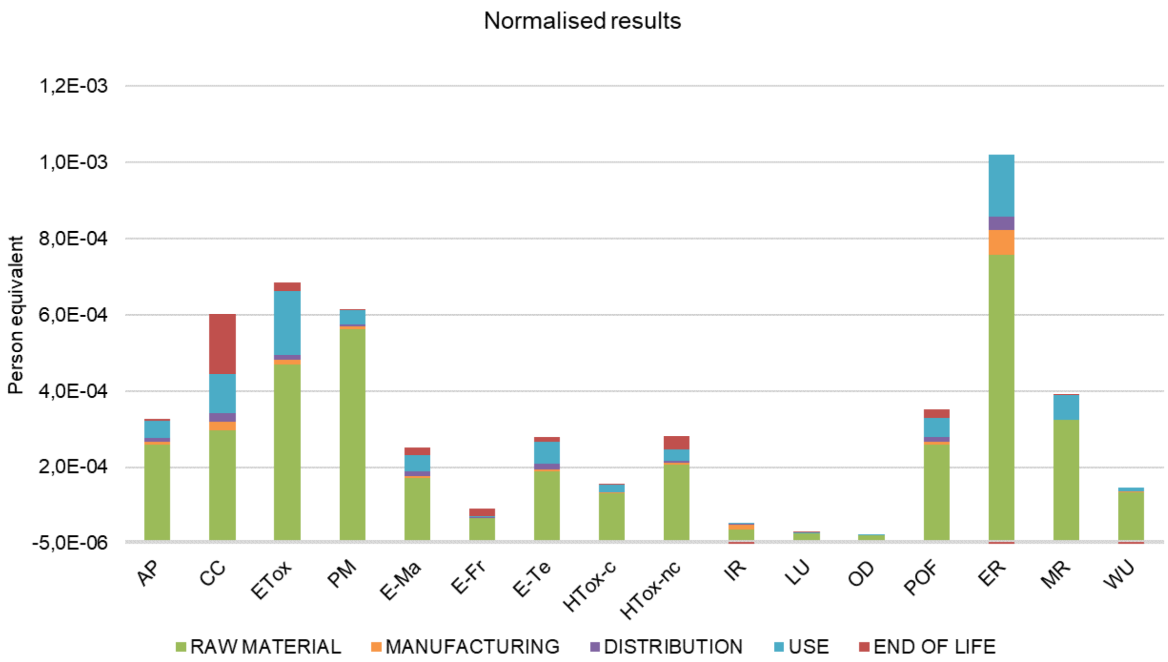
Although additives only make up approx. 6.5% of the total ingredients in outdoor paint, they are the second largest contributor to overall impacts and the biggest contributor to OD.

Finally, both primary and tertiary packaging have an overall low impact, although the former contributes the most to CC-biogenic and the latter to LU. Primary packaging includes the production of the steel can and polypropylene parts, whereas tertiary packaging includes polyethylene film and wooden pallets.

4.3.3.2.2 Normalised results for outdoor paint products

The characterised results presented above are normalised using the EF 3.1 normalisation factors, which can be found in section 4.3.1.2.3. Figure *30* shows the normalised results within all impact categories.

Figure 30. Normalised results of an average outdoor paint presented in Person Equivalent (using EF 3.1 normalisation factors) for different impact categories.



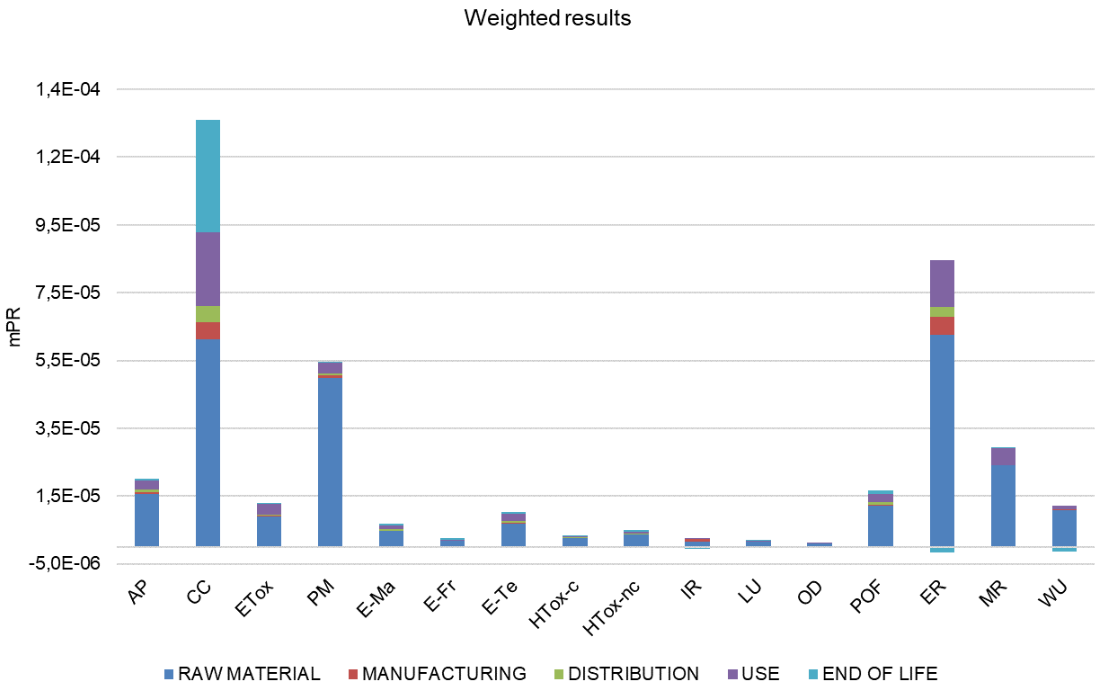
Source: Own elaboration based on LCIA results.

The highest impacts are seen for ER, CC, ETox and PM. The raw material stage has the highest contribution to all three impact categories, followed by the EoL stage for CC and the use stage for the remaining three categories. The lowest normalised impacts are seen for OD and LU.

4.3.3.2.3 Weighted results for outdoor paint products

Weighting the LCA results is a mandatory step in the PEF methodology. During weighting, the normalised results are multiplied by weighting factors reflecting the importance of the different life cycle impact categories. The weighting factors can be found in section 4.3.1.2.3.

Figure 31. Weighted results of an average outdoor paint presented in Person Equivalent (using EF 3.1 normalisation factors) for different impact categories.



Source: Own elaboration based on LCIA results.

Figure *31* shows the contribution of each life cycle stage to different impact categories. According to the results, the highest impacts are seen for CC and ER, whereas the lowest are seen for OD, E-Fr, LU and IR.

Table *44* shows the sum of weighted results per life cycle stage. The weighted results are aggregated across all impact categories obtaining an overall score for each life cycle stage. The results show that the raw material stage accounts for 69.8% of impacts, followed by the use stage with 15.0%. The distribution stage has the lowest contribution, with only 2.8%.

Table 44. Weighted results using the EF 3.1 weighting factors provided by the European Commission.

Life cycle stage	Value	Unit	% share
Raw material	2.69E-04	mPR	69.8%
Manufacturing	1.38E-05	mPR	3.6%
Distribution	1.09E-05	mPR	2.8%
Use	5.77E-05	mPR	15.0%
End-of-life	3.42E-05	mPR	8.9%
TOTAL	3.86E-04	mPR	100%

Source: Own elaboration.

4.3.3.2.4 Interpretation of EFIA results for outdoor paint products

The most relevant impact category, lifecycle stages (LCS), and processes are identified and presented in Table *45*. The calculation method behind the contributions is equal to those described for indoor paint product in section 4.3.2.2.4.

Table 45. Overview of the most relevant impact categories, lifecycle stages, and processes of outdoor paint products.

Most relevant impact category	%	Most relevant LCS	%	Most relevant processes	%
Climate change	32%	LCS1	49%	Vinyl acetate	39%
		LCS4	17%	Application	17%
		LCS5	26%	EoL dried paint	23%
				Manufacturing	4%
Energy resources: non-renewable	22%	LCS1	73%	Vinyl acetate	58%
		LCS4	16%	Application	15%
				Manufacturing	6%
				Packaging primary	4%
Particulate matter formation	14%	LCS1	92%	Vinyl acetate	80%
Material resources: metals/minerals	7%	LCS1	82%	Vinyl acetate	75%
Acidification	5%	LCS1	79%	Vinyl acetate	65%
				Polyoxyethylene (25) octyl phenyl ether	3%
				Application	14%

Source: Own elaboration.

The most relevant impact category for outdoor paint products is Climate change accounting for 32% of the total impact, followed by Energy resources: non-renewable (22%), Particulate matter formation (14%), Material resources: metals/minerals (7%), and Acidification (5%).

LCS1 – raw material acquisition and pre-processing is the most relevant LCS within all most relevant impact categories, contributing between 49% (Climate change) and 92% (Particulate matter formation). For Particulate matter formation, Material resources, and Acidification LCS1 is the only LCS categories as most relevant. For Climate change other relevant LCS are LCS4 and LCS5 (Use 17% and End of life 23%).

Vinyl acetate is the most relevant process within all the most relevant impact categories, accounting for between 39% (Climate change) and 80% (Particulate matter formation). Large attention should be given to the formulation of outdoor paints in the development of new EU Ecolabel criteria. Lastly, the end of life of the dried paint is a relevant process within Climate change (23%), which is send to landfill.

4.3.3.2.5 Summary of EFIA of outdoor paint

Conducting the EFIA study revealed the following conclusions:

- The raw material acquisition and preprocessing stage is the most contributing life cycle stage when assessing the environmental performance of covering one square meter of substrate with outdoor paint for 50 years. Most of impacts during this stage are related to binder production.
- The use stage is the second most impactful stage, of which the application of paint on the substrate has a particular high impact.
- The highest normalised impacts are seen within ER, ETox, PM and CC categories.
- The weighted results revealed the raw material stage to account for approx. 70% of the environmental impacts of outdoor paint, followed by the use stage with nearly 15%.

4.3.4 EFIA of outdoor varnish products

The Environmental Footprint Impact Assessment (EFIA) of decorative outdoor varnishes is provided below.

4.3.4.1 Background information and assumptions

Definition of the product: For the purpose of this LCA screening, outdoor varnishes are considered as coatings used to cover exterior wood substrate and fall under the scope of the Paints Directive 2004/42/EC.

Functional unit and reference flows: The functional unit (FU) is the protection and decoration of 1 m^2 of outdoor wood substrate for 50 years at a specified quality level.

The amount of varnish required to cover 1 m^2 of substrate differs depending on the composition of the varnish, type of substrate, application method, and other factors.

These factors are generally product specific and differ amongst varnishes and amongst companies. Due to lack of data, the values in the PEFCR for outdoor wood (varnish) are used and are assumed to be representative of a classic varnish.

- Coverage: 9.5 m^2/L
- Applied paint: 0.89
- Paint density: 1.36 kg/L
- Maintenance multiplier: 7.46

Therefore, the reference flow for varnishes is calculated:

$$\text{kg of varnish} = 1\ m^2 / 9.5\ m^2/L / 0.89 \times 1.36\ kg/L \times 7.46 = 1.200\ kg$$

The amount of varnish for outdoor wood required per FU is 1.200 kg.

Formulation

Exterior wood varnishes are typically made with alkyd, acrylic or polyurethane resins. Acrylic resins have high molecular weight, resulting in a higher film strength and therefore higher durability[133]. These resins are also known for their UV resistance and resistance to yellowing, making them ideal for outdoor use. For that reason, the formulation of acrylic varnishes is being studied.

Solvents generally make up 30 to 50 % of most varnishes and are added to dissolve the resin and adjust the viscosity in order to allow the varnish to be easily applied. These solvents can either be organic liquids, such as mineral spirits, toluene and xylene, or water. Different solvents can also be mixed, creating formulations which reduce the drying time and improve the application of the varnish. Water-based varnish formulations were developed to reduce the amounts of VOCs in varnishes. For that reason, the formulation of a water-based varnish is chosen.

Finally, varnishes also include additives, which change the properties of the paints. Surfactants, defoamers, UV-stabilizers, wetting and dispersing agents are typical additives in water-based varnish formulations.

A review of existing literature on the composition of water-based acrylic varnishes was carried out. Most existing literature on this type of varnish is either outdated or does not include formulations. However, recent literature provided basic formulations including the components of varnishes. The formulation of a waterborne acrylic wood varnish with UV absorber[134] was chosen. This formulation is shown in Table *46* and was based on the raw materials of acrylic varnishes supplied to the authors by BASF in Turkey.

Table 46. Formulation of acrylic water-based varnish.

Ingredient	Weight (%)
Acrylic resin	73.7
UV absorber	6.0
Film-forming agents	0.67
Defoamers	1.0
Dispersing agent	0.6
Rheology modifier	1.3
Water	16.73
TOTAL	100

133 See: Nejad, M., & Cooper, P. (2017). Exterior Wood Coatings. InTech. doi: 10.5772/67170: https://www.intechopen.com/chapters/53959

134 See: Özgenç Keleş, Özlem & Bilici, Ebru & Durmaz, Sefa & Emik, Serkan. (2020). Some Physical and Chemical Properties of Acrylic Varnish Systems with Bark Extract and UV Absorber.

Source: Adapted from Özgenç Keleş, Özlem & Bilici, Ebru & Durmaz, Sefa & Emik, Serkan. (2020). Some Physical and Chemical Properties of Acrylic Varnish Systems with Bark Extract and UV Absorber.

Raw material acquisition and preprocessing: The composition of an average wood varnish is based on the formulation above from Keleş et al. (2020) and is shown together with LCI processes from the EF 3.1 database in Table *47*.

Although the formulation in Table 46 includes the components of varnishes, the specific chemical compounds are unknown, e.g., defoamers amount to 1 % of the weight of acrylic varnishes, yet no data is provided for what chemical compound these defoamers are made of. For that reason, research on each type of component was conducted and specific chemical compounds on EF 3.1 database were selected, based on functionality.

Table 47. LCI of a standard formulation of an average outdoor varnish using the EF 3.1 database.

Ingredient	%	EF 3.1 process
Acrylic resin	73.7	Acrylic binder production {EU+EFTA+UK} | technology mix | production mix, at plant | 100% active substance | LCI result
UV absorber	6.0	Hindered amine light stabilizers (HALS) {GLO} | production mix, at plant | Hindered amine light stabilizers (HALS) for addition to polymers prior to yarn spinning. | LCI result
Film-forming agents	0.67	Glycerol esters (glycerol monostearate, GMS) ethoxylated amines {GLO} | production mix, at plant | Glycerol esters for use within polymers prior to yarn spinning. | LCI result
Defoamers	1.0	Antifoaming agent, silicone emulsion production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result
Dispersing agent	0.6	Dispersing agent (unspecific) production {GLO} | technology mix | production mix, at plant | 100% active substance | LCI result
Rheology modifier	1.3	Thickener {GLO} | production mix, at plant | Chemical compound used in footwear manufacturer. | LCI result
Water	16.73	Tap water {EU+EFTA+UK} | average technology mix | consumption mix, at consumer | Technology mix for supply of drinking water to users | LCI result

Source: Own elaboration.

Primary, secondary, and tertiary packaging is included in this phase of the life cycle. The composition is also derived from the PEFCR LCI for Decorative Paints and is shown in Table *48* together with the LCI processes used in the study.

In addition, the transport of the raw materials and packaging are included in this stage. According to the PEFCR, the raw materials are transported 460 km to the production location, whereas the packaging materials are transported 250 km. The transportation takes place by truck and a utilization rate of 64% is used, according to the PEFCR.

Table 48. LCI of both primary, secondary and tertiary packaging for outdoor wall varnish.

Type of packaging	Amount	EF 3.1 process
Primary (sales packaging):	Per FU	
Steel can	0.0073 kg	Steel tinplated {EU+EFTA+UK} | blast furnace route | single route, at plant | 1kg, typical thickness between 0.13 - 0.49 mm. typical width between 600 - 1100 mm. | LCI result
PP parts	0.0374 kg	PP granulates {EU+EFTA+UK} | polymerisation of propene | production mix, at plant | 0.91 g/cm3, 42.08 g/mol per repeating unit | LCI result
PP parts	0.0356 kg	Polypropylene (PP) fibers {EU+EFTA+UK} | polypropylene production, spinning | production mix, at plant | 5% loss, 3.5 MJ electricity | Partly terminated system

Type of packaging	Amount	EF 3.1 process
Secondary (grouped packaging):	Per FU	
Cardboard	0.0008 kg	Corrugated box, uncoated {EU+EFTA+UK} | Kraft Pulping Process, pulp pressing and drying | production mix, at plant | 280 g/m2, R1=88% | LCI result
Tertiary (transport packaging):	Per FU	
PE film	0.0009 kg	Plastic, stretch film {EU+EFTA+UK} | raw material production, plastic extrusion | production mix, at plant | thickness: 30 um, grammage: 0,02754 kg/m2 | LCI result
Wooden pallet	0.0474 kg	Pallet, wood (80x120) {EU+EFTA+UK} | sawing, piling, nailing | single route, at plant | 25 kg/piece, nominal loading capacity of 1000kg | LCI result

Source: Own elaboration.

Manufacturing: In the manufacturing stage, the use of electricity, water, heat, and output of wastewater has been included. The data for electricity, heat, light fuel oil, and water usage are based on the PEFCR for decorative paints. According to the PEFCR, there are 3% paint losses during the manufacturing stage, which have been included in this study.

Distribution: The distribution stage includes the transport of the paint from the factory to the Regional Distribution Centre (RDC) and to the Point of Sale (PoS). According to the PEFCR, the package paint is transported 350 km by truck to the RDC and 370 km to the PoS. In addition, a total utilization rate of the trucks is 64%. Furthermore, as defined by section 4.4.5 of the PEF Recommendation, both lighting and heating of storage in distribution centre and retail has been included and the data is taken from the PEFCR LCI for Decorative Paints. To account for losses during distribution, a 1% loss of paint at the RDC and a 1% loss of paint and packaging at PoS have been included according to PEFCR.

Use: In the use stage, the application of paint requires auxiliary materials, which are included in this study. Losses during application are also accounted for and according to the PEFCR, 89% of the paint (application factor) is applied and the remaining 11% is lost and treated as non-hazardous waste at the end-of-life stage.

End-of-life: The end-of-life stage consists of the transport of waste, waste processing in the form of recycling, incineration with energy recovery and landfilling. Each waste material is transported 80 km to its end-of-life treatment, with a truck utilization rate of 64%.

The end-of-life in this case covers the final disposal of the substrate with indoor paint in a landfill. It also includes the waste treatment of hazardous and non-hazardous waste generated during manufacturing and use, 45% of which is incinerated and 55% of which is landfilled, according to the PEFCR. Finally, packaging is assumed to be incinerated with energy recovery.

Data quality: The assessment of the data quality is split up into the different life cycle stages; raw material acquisition and pre-processing (LCS1), manufacturing (LCS2), distribution stage (LCS3), use stage (LCS4), and End of Life (LCS5).

- LCS1: Data quality regarding the average composition of outdoor varnish is fair. Although formulation data from manufacturers for an average outdoor varnish was unavailable, the ingredient data for an acrylic water-based outdoor varnish collected from 2020 is deemed representative of an outdoor varnish today. The data quality for packaging is good and was collected from the PEFCR's LCI for decorative paints.
- LCS2: The data quality of the manufacturing process was retrieved from the PEFCR's LCI and is deemed good. The datasets used from the EF 3.1 database for electricity, light fuel oil, natural gas, water and wastewater treatment are good.
- LCS3: Data regarding the distribution stage was also retrieved from the PEFCR's LCI. The quality of the LCI data and the datasets used is good.
- LCS4: The data inputs are retrieved from the PEFCR's LCI and data quality of this stage is good. For some materials, no LCI data was available in the EF 3.1 database and ecoinvent datasets were used.

— LCS5: The data in the End-of-Life stage is based on the PEFCR's LCI and accounts for the disposal of waste through landfill or incineration. However, the LCI does not account for recycling of materials. The overall data quality of this life cycle stage is fair.

The data used in this study represents average outdoor varnishes. Hence, the results do not address the environmental performance of individual products. No data was found on the factors affecting the reference flow (coverage, varnish density, maintenance multiplier) for the specific formulation used. As a result, the reference flow was based on the factors provided in the PEFCR.

4.3.4.2 Life cycle impact assessment (LCIA) for outdoor varnish: results and interpretation

4.3.4.2.1 Contribution analysis for outdoor varnish products

A contribution analysis was made to identify hotspots in the life cycle stages of outdoor varnishes, the results are presented below.

Table 49. Characterised, normalised and weighted impacts of outdoor varnishes.

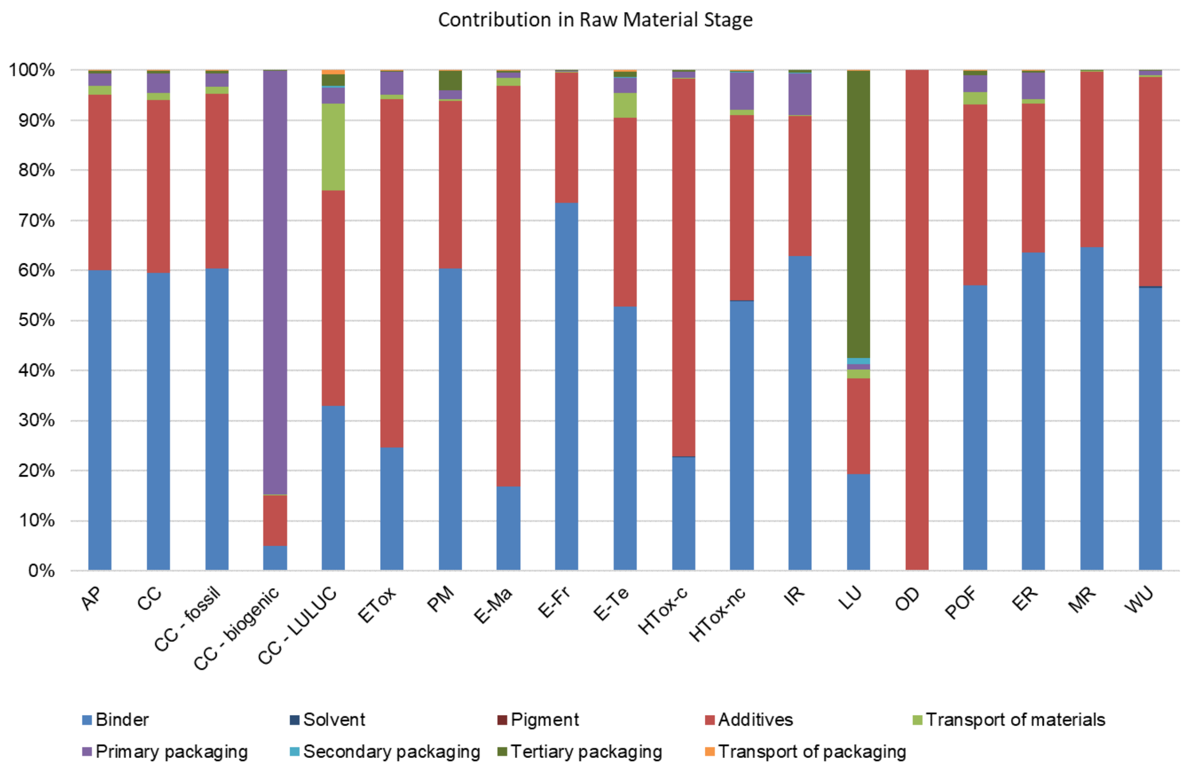
Impact category	Characterised impact						Normalised impact	Weighted impact
	Raw material acquisition	Manufacturing	Distribution	Use	End-of-Life	Total		
Acidification [mol of H^+ eq]	1.21E-02	5.59E-04	6.43E-04	3.75E-03	-3.14E-04	1.68E-02	3.01E-04	1.87E-05
Climate Change [kg CO_2 eq]	2.52E+00	2.12E-01	1.97E-01	1.15E+00	8.68E-01	4.95E+00	6.55E-04	1.38E-04
Climate Change (fossil) [kg CO_2 eq]	2.48E+00	1.95E-01	1.85E-01	1.14E+00	8.00E-01	4.80E+00	-	-
Climate Change (biogenic) [kg CO_2 eq]	4.25E-02	1.72E-02	1.16E-02	4.88E-03	6.81E-02	1.44E-01	-	-
Climate Change (land use and land use change) [kg CO_2 eq]	1.46E-03	2.77E-05	6.28E-04	3.86E-03	7.47E-05	6.06E-03	-	-
Ecotoxicity – freshwater [CTUe]	3.51E+01	7.03E-01	8.99E-01	1.42E+01	-3.41E-01	5.06E+01	8.92E-04	1.71E-05
Particulate matter [Disease incidence]	2.13E-07	5.48E-09	3.13E-09	3.18E-08	-1.71E-10	2.54E-07	4.26E-04	3.82E-05
Eutrophication – marine [kg N eq]	6.64E-03	1.07E-04	2.83E-04	1.26E-03	8.33E-05	8.37E-03	4.28E-04	1.20E-05
Eutrophication – freshwater [kg P eq]	2.19E-04	5.90E-07	9.05E-07	1.07E-05	2.52E-06	2.33E-04	1.45E-04	4.30E-06
Eutrophication – terrestrial [mol N eq]	2.35E-02	1.12E-03	3.12E-03	1.52E-02	1.16E-03	4.41E-02	2.50E-04	9.26E-06
Human toxicity – cancer [CTUh]	3.55E-09	2.77E-11	3.00E-11	4.67E-10	-1.85E-11	4.05E-09	2.35E-04	5.00E-06
Human toxicity – non-cancer [CTUh]	2.21E-08	7.81E-10	7.73E-10	5.59E-09	9.91E-10	3.03E-08	2.35E-04	4.33E-06
Ionising Radiation [kBq U^{235} eq]	1.18E-01	6.63E-02	6.81E-03	1.66E-02	-5.81E-02	1.49E-01	3.54E-05	1.77E-06
Land Use [Pt]	1.56E+01	2.50E-01	7.30E-01	3.61E+00	4.42E-01	2.07E+01	2.52E-05	2.00E-06
Ozone Depletion [kg CFC-11 eq]	1.60E-05	5.12E-11	4.41E-12	1.31E-10	-4.55E-11	1.60E-05	3.05E-04	1.93E-05
Photochemical Ozone Formation [kg NMVOC eq]	8.02E-03	3.32E-04	5.94E-04	3.04E-03	9.26E-05	1.21E-02	2.96E-04	1.41E-05
Resource depletion – fossils [MJ]	5.75E+01	4.86E+00	2.67E+00	1.57E+01	-6.10E+00	7.47E+01	1.15E-03	9.56E-05
Resource depletion – minerals and metals [kg Sb eq]	1.35E-05	2.95E-08	4.19E-08	6.29E-06	8.27E-08	1.99E-05	3.13E-04	2.37E-05
Water use [m^3 world eq]	1.28E+00	3.19E-02	8.17E-03	1.67E-01	-1.14E-01	1.37E+00	1.20E-04	1.02E-05

Source: Own elaboration.

Generally, the most contributing life cycle stage to the impact of covering 1 m^2 of outdoor wood substrate for 50 years with a minimum 98% opacity is the raw material stage, followed by the use stage. The negative impacts (i.e. environmental benefits) in impact categories AP, ETox, PM, HTox-c, IR, LU, OD, ER and WU are due to the incineration with energy recovery of materials during the EoL stage. The impacts related to the use stage primarily stem from the application of paint on the substrate.

The raw material stage consists of many sub-processes. The contribution of these sub-processes to the total impact of the raw material and preprocessing stage is evaluated in Figure *32*.

Figure 32. Characterised results for outdoor varnishes life cycle stages, presented in percentage of total impact, split by life cycle stage for each of the impact categories.



Source: Own elaboration based on LCIA results.

Binder production, in this case acrylic resin binder, is the biggest contributor to 12 out of 19 impact categories within the raw material life cycle stage. Although additives only make up less than 10% of the total ingredients in outdoor varnish, they are the second largest contributor to overall impacts and the biggest contributor to CC-LULUC, ETox, E-Ma, HTox-c and OD.

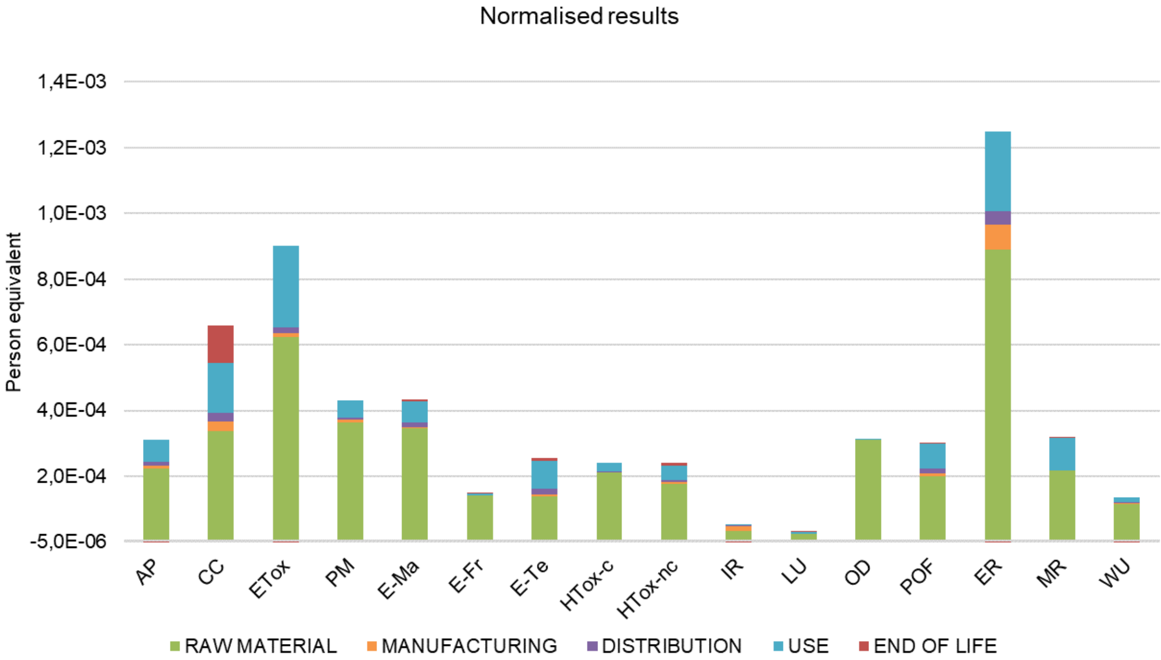
Finally, both primary and tertiary packaging have an overall low impact, although the former contributes the most to CC-biogenic and the latter to LU. Primary packaging includes the production of the steel can and polypropylene parts, whereas tertiary packaging includes polyethylene film and wooden pallets.

The outdoor varnish studied does not have pigment, therefore no impacts are registered for this component.

4.3.4.2.2 Normalised results for outdoor varnish products

The characterised results presented above are normalised using the EF 3.1 normalisation factors, which can be found in section 4.3.1.2.3. Figure *33* shows the normalised results within all impact categories.

Figure 33. Normalised results of an average outdoor varnish presented in Person Equivalent (using EF 3.1 normalisation factors) for different impact categories.



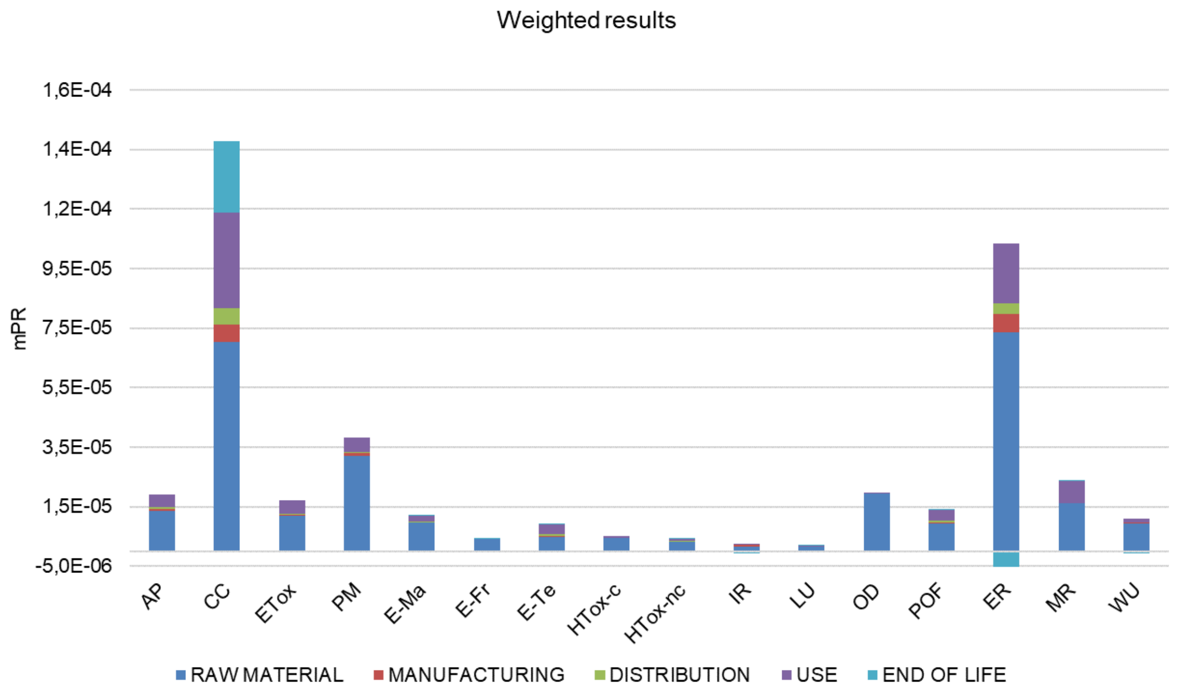
Source: Own elaboration based on LCIA results.

The highest impacts are seen for ER, ETox and CC. The raw material stage has the highest contribution to all three impact categories, followed by the use stage. The lowest normalised impacts are seen for LU and IR.

4.3.4.2.3 Weighted results for outdoor varnish products

Weighting the LCA results is a mandatory step in the PEF methodology. During weighting, the normalised results are multiplied by weighting factors reflecting the importance of the different life cycle impact categories. The weighting factors can be found in section 4.3.1.2.3.

Figure 34. Weighted results of an average outdoor varnish presented in Person Equivalent (using EF 3.1 normalisation factors) for different impact categories.



Source: Own elaboration based on LCIA results.

Figure *34* shows the contribution of each life cycle stage to different impact categories. According to the results, the highest impacts are seen for CC and ER, whereas the lowest are seen for LU and IR.

Table *50* shows the sum of weighted results per life cycle stage. The weighted results are aggregated across all impact categories obtaining an overall score for each life cycle stage. The results show that the raw material stage accounts for 68.8% of impacts, followed by the use stage with 20.6%. The distribution stage has the lowest contribution, with only 3.0%.

Table 50. Weighted results using the EF 3.1 weighting factors provided by the European Commission.

Life cycle stage	Value	Unit	% share
Raw material	2.85E-04	mPR	68.8%
Manufacturing	1.58E-05	mPR	3.8%
Distribution	1.26E-05	mPR	3.0%
Use	8.53E-05	mPR	20.6%
End-of-life	1.51E-05	mPR	3.7%
TOTAL	4.13E-04	mPR	100%

Source: Own elaboration.

4.3.4.2.4 Interpretation of EFIA results for outdoor varnish products

The most relevant impact category, lifecycle stages (LCS), and processes are identified and presented in Table *51*. The calculation method behind the contributions is equal to those described for indoor paint product in Section 4.3.2.2.4.

Table 51. Overview of the most relevant impact categories, lifecycle stages, and processes of outdoor varnish products.

Most relevant impact category	%	Most relevant LCS	%	Most relevant processes	%
Climate change	32%	LCS1	51%	Acrylic resin	30%
				UV absorber	12%
		LCS4	23%	Application	23%
		LCS5	18%	EoL dried paint	14%
				Manufacturing	4%
Energy resources: non-renewable	26%	LCS1	66%	Acrylic resin	42%
				UV absorber	15%
		LCS4	18%	Application	18%
				Manufacturing	6%
Particulate matter formation	9%	LCS1	84%	Acrylic resin	50%
				UV absorber	15%
				Defoamer	8%
		LCS4	13%	Application	12%
Material resources: metals/minerals	6%	LCS1	68%	Acrylic resin	44%
				UV absorber	16%
		LCS4	32%	Application	31%
Ozone depletion	4,5%	LCS1	100%	Defoamer	100%
Acidification	4,5%	LCS1	70%	Acrylic resin	41%
				UV absorber	13%
				Defoamer	7%
		LCS4	22%	Application	21%

Source: Own elaboration.

The most relevant impact category for outdoor paint products is Climate change accounting for 32% of the total impact, followed by Energy resources: non-renewable (26%), Particulate matter formation (9%), Material resources: metals/minerals (6%), Ozone depletion (5.5%), and Acidification (4.5%).

LCS1 – raw material acquisition and pre-processing is the most relevant LCS within all most relevant impact categories, contributing between 51% (Climate change) and 100% (Ozone depletion). LCS4 (Use stage) is a relevant LCS within 5 of 6 impact categories, the exception being Ozone depletion. Within Climate change LCS5 is also considered a most relevant LCS.

The most relevant process within 5 of 6 impact categories is acrylic resin accounting for 30% to 50% followed by UV absorber. Large attention should be given to the formulation of the varnish as it is found to be of importance when assessing the environmental performance of outdoor varnish. The application process which mainly consists of transport is also identified as a relevant process within 5 of the impact categories. However, this factor is difficult to address in the ecolabel criteria.

4.3.4.2.5 Summary of EFIA of outdoor varnish

Conducting the EFIA study revealed the following conclusions:

- The raw material acquisition and preprocessing stage is the most contributing life cycle stage when assessing the environmental performance of covering one square meter of substrate with outdoor varnish for 50 years. Most of impacts during this stage are related to binder and additives production.
- The use stage is the second most impactful stage, of which the application of paint on the substrate has a particular high impact.
- The highest normalised impacts are seen within ER, Etox, and CC categories.

- The weighted results revealed the raw material stage to account for approx. 69% of the environmental impacts of outdoor paint, followed by the use stage with nearly 21%.

4.3.5 Sensitivity Analysis

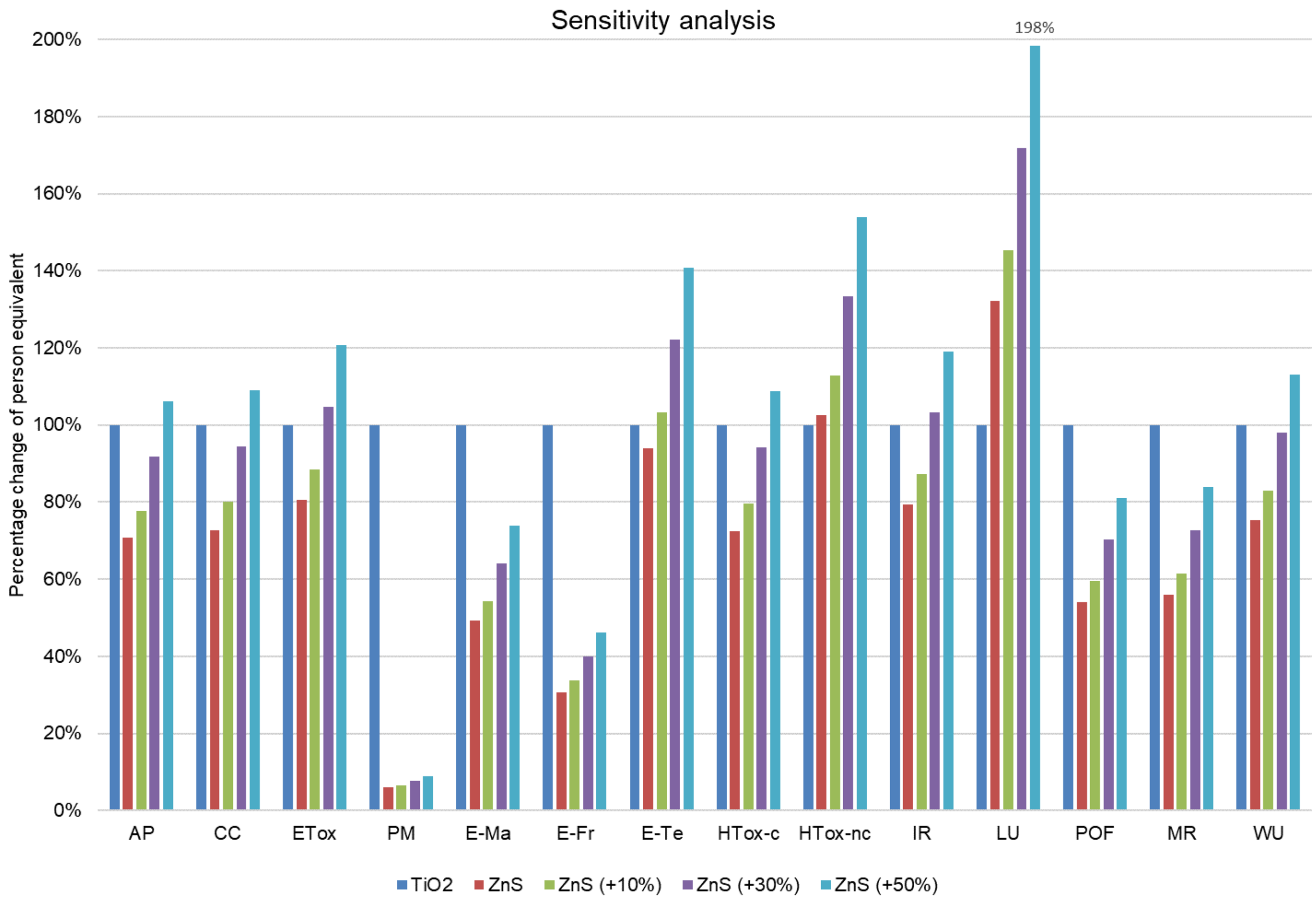
4.3.5.1 Alternative to titanium dioxide (TiO2)

Titanium dioxide is widely used as pigment for all types of coatings, except clear varnishes. Due to its high refractive index, it is generally used to obtained whiteness and good opacity. However, this compound is now classified as a carcinogen if inhaled for TiO_2 particles <10um in aerodynamic diameter, following Delegated Regulation (EU) 2020/217. Although this regulation was annulled by the European Court of Justice in 2022, this decision has since been appealed. For this reason, alternative white pigments are now being considered more and used more widely in products on the market. Furthermore, as seen from the LCA screenings in section 4.2 and 4.3, Titanium dioxide is the single paint ingredient with the highest environmental impact across all impact categories. Therefore, it is relevant to look into the impact of some of the alternative white pigments in the market.

Zinc sulphide (ZnS) is a white pigment, which is used as one of the alternatives for titanium dioxide. However, it has a lower scattering coefficient, meaning more pigment is required to achieve the same opacity as titanium dioxide pigment. It requires a 1.9 layer thickness to achieve the same hiding power as TiO_2, which would require the application of 1.9 times the number of coats.

A sensitivity analysis was conducted to study the impact of changing from titanium dioxide pigment to zinc sulphide. In this scenario, 1 kg of TiO_2 (baseline) is compared with 1 kg of ZnS, as well as increases in the amount of ZnS – increases of 10%, 30% and 50%.

Figure 35. Relative changes (TiO_2 set at 100%) to normalised results for three different sensitivity analyses, based on different amounts of ZnS.



Source: Own elaboration.

Figure 35 shows the results of four sensitivity scenarios in relation to the baseline (1 kg of TiO_2). These scenarios compare the production of 1 kg of titanium dioxide and zinc sulphide in different amounts (1 kg, +10%, +30% and +50%). The "ZnS" scenario scores lower for most impact categories, excluding HTox-nc (+3%) and LU (+32%). In particular, zinc sulphide scores significantly lower for PM (-94%), E-Fr (-69%) and E-Ma (-51%). Therefore, 1 kg of zinc sulphide has an overall lower impact than 1 kg of titanium dioxide.

However, due to the lower performance of zinc sulphide, higher quantities are required to reach similar levels of opacity. By increasing the amount of ZnS by 10%, the impacts on E-Te are surpassed (+3%), in addition to the already exceeding scores of ZnS. An increased 30% amount of ZnS scores higher on ETox (+5%) and IR (+3%), whereas a 50% increase in the amount of ZnS leads to a higher score for AP (+6%), CC (+9%), HTox-c (+9%) and WU (+13%).

OD and ER were removed from the results presented in Figure 35 due to the magnitude of score difference between the scenarios and the baseline. In relation to OD, "ZnS" scores 795% higher than TiO_2, whereas "ZnS (+50%)" scores 1242% higher. On the other hand, the impact of "ZnS" on ER is 155% higher than titanium dioxide, with "ZnS (+50%) scoring 282% higher.

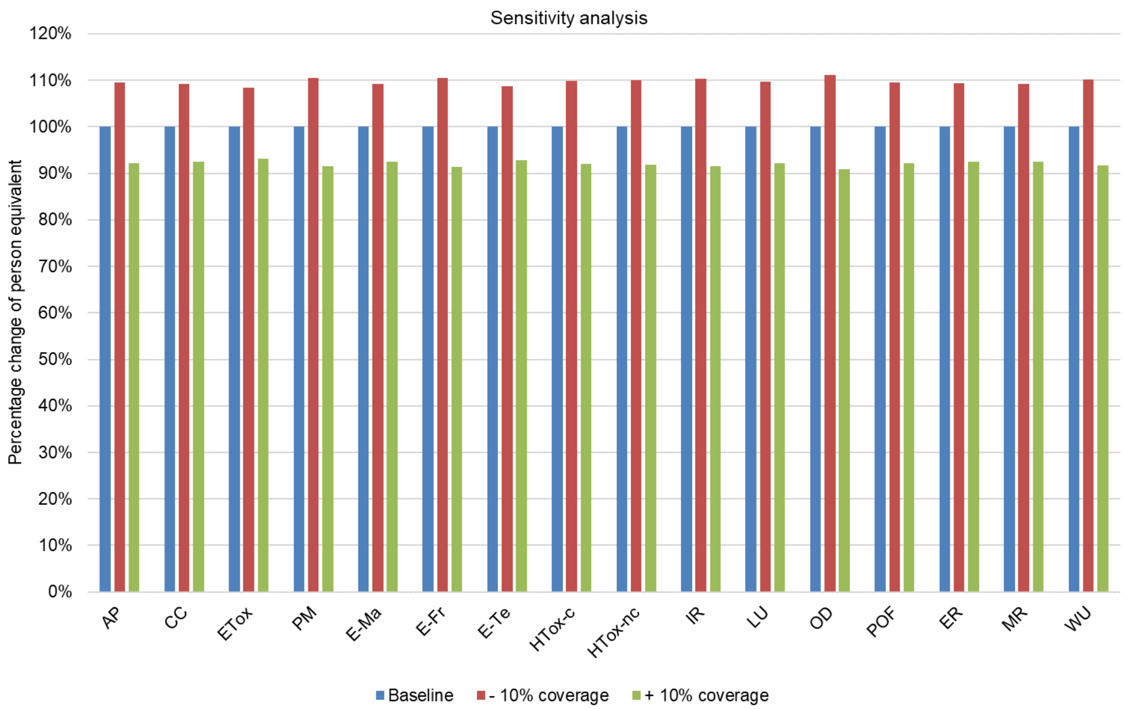
However, to reach equivalence in terms of opacity performance, 1.9 kg of ZnS would be required. A 90% increase of ZnS would result in overall high impacts across categories, except for PM, E-Ma and E-Fr. For this reason, zinc sulphide does not seem to be a good alternative to titanium dioxide as white pigment.

4.3.5.2 Assessing sensitivity of the spreading rate of outdoor paint

The spreading rate influences the amount of paint needed to achieve the desired protection and decoration of the painted wall. A higher spreading rate (m^2/L) will result in a reduced amount of paint needed for the same area. To assess the importance of the spreading rate a sensitivity analysis was conducted increasing and decreasing the spreading rate with 10%. The sensitivity analysis was carried out on outdoor paint with the original spreading rate of 7 m^2/L.

The change in spreading rate results in new reference flows of 1.159 kg and 0.948 kg of paint compared to the original 1.043 kg in the baseline scenario. No changes were made to the formulation of the outdoor paint. Figure *36* presents the results of the sensitivity analysis related to spreading rate.

Figure *36*. Sensitivity analysis on the coverage rate of outdoor paint. Increasing and decreasing the coverage with 10%.



Source: Own elaboration

It is evident that the increase and decrease of the spreading rate with 10% shows a linear relationship in the results. A 10% decrease in the spreading rate result in an increase in impact of between 8 and 10% depending on the impact category. An increase in spreading rate, by contrast, reveals a decrease in impact of 7 to 9%. Designing a paint with high spreading rate might potentially decrease the impacts of the paint as less paint is needed. However, this conclusion assumes that the formulation remained the same.

4.3.5.3 Paints without preservatives

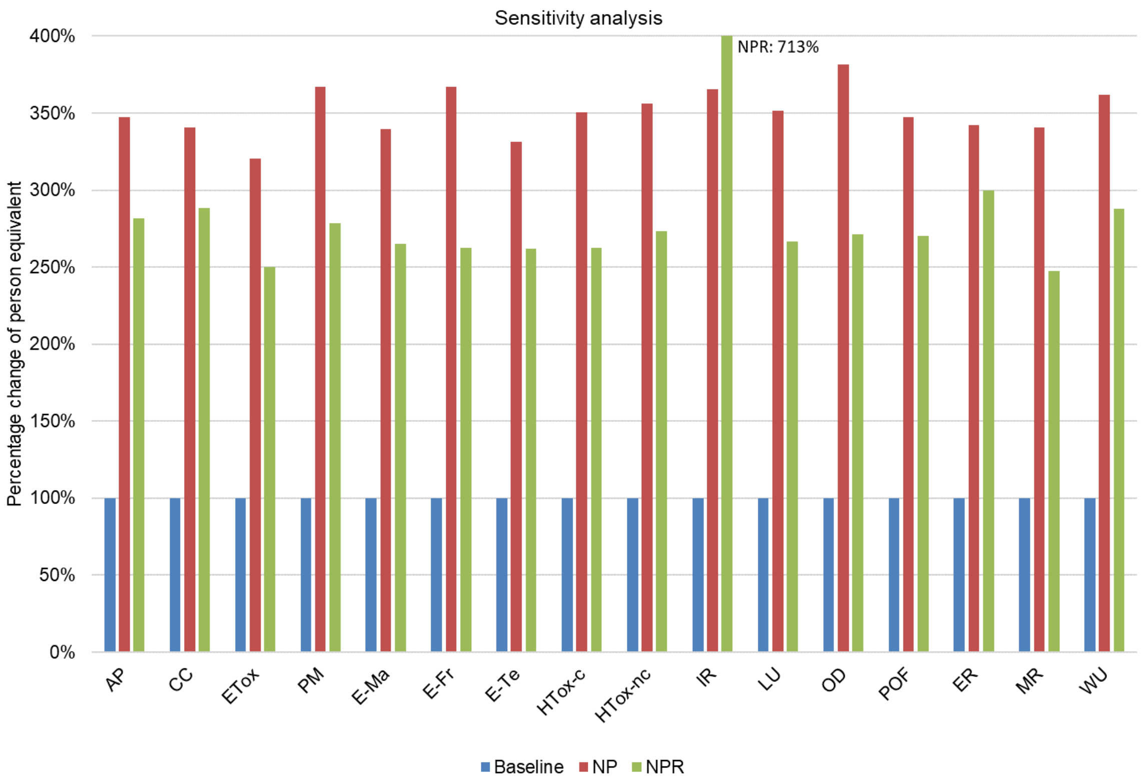
Paints commonly include preservatives in their formulation, to keep bacteria from spoiling the paint. However, there is currently regulatory pressure to reduce biocides due to its harmful impacts on human health and the environment. To study the environmental impacts of producing preservative-free paints, a sensitivity analysis was conducted. This analysis considers two scenarios, based on the water-based acrylic outdoor paint (baseline) studied in section 4.3.3:

1) Outdoor paint without preservatives (NP)
2) Outdoor paint without preservatives, but assumed to be refrigerated (NPR)

In these two scenarios, preservatives (formaline and biocide) were removed from the formulation. To ensure a mass balance, the water content on the formulation was adjusted. In scenario 2, refrigeration during storage is added as a method to preserve the paint. The energy requirements for refrigeration (2 MJ/kg) are based on an LCA from American Coatings Association, studying the impacts of preservatives on water-based paints. The spoilage rates and dry-film lifetime for both scenarios are also based on the same LCA: paint without preservatives (NP) has a product spoilage of 50% and paint without preservatives and refrigerated (NPR) has a spoilage of 2%; both paints have a 3-year lifetime, meaning throughout the 50 years studied, the substrate needs to be coated every 3 years.

Due to its spoilage rate and lifetime, 5.77 kg of NP outdoor paint are required to paint 1 m^2 of substrate throughout 50 years. On the other hand, if this paint is refrigerated during storage (NPR), the spoilage rate decreases to 2%, resulting in 4.10 kg of NPR outdoor paint required to coat the substrate for 50 years. Figure *37* presents the results of the sensitivity analysis.

Figure 37. Relative changes to normalised results for three different sensitivity analyses, based on different amounts of ZnS.



Source: Own elaboration.

Figure 37 shows that preservative-free paints have a significantly higher impact across impact categories than the formulation containing preservatives. The impacts of preservative-free paint (NP) are 220 to 267% higher than the baseline, depending on the impact category. In addition, refrigerated preservative-free paint (NPR) has impacts 150 to 200% higher than the baseline for all impact categories, excluding IR, for which the impact of NPR is 613% higher than the baseline. However, this analysis assumes that in the formulation, the preservatives are substituted by adding more water, which may not represent what occurs when preservatives are removed from formulations.

The preservatives for the outdoor paint studied account for 0.15% of the total paint ingredients. However, when removed from the formulation, the paint's quality and lifespan decreases, resulting in spoilage of the paint. Despite the adverse effects on human health and the environment, paints containing preservatives perform better than preservative-free paints from an environmental perspective. Therefore, new and better preservation methods may be required to increase the lifetime and quality of the paint, while ensuring in-can preservatives are not present.

4.3.6 Conclusions

LCA screenings have been conducted for 3 different types of decorative paint products that are within the scope of the EU Ecolabel criteria, namely indoor wall paint, outdoor wall paint, and outdoor wood varnish.

It should be noted that there are other types of paint products also covered by the EU Ecolabel criteria that have not been analysed, for example: indoor wood varnish. In addition, only water-based acrylic paints and varnishes were studied, thereby excluding paints made with other binders, solvents, pigments, and additives.

These LCA screenings were limited by a lack of primary data for product formulations and reference flows. Thus much of this information was taken from the literature review and the PEFCR LCI. The main conclusions are:

- The raw material stage leads to the most impacts for all three paint products, of which the binder caused the highest impact for outdoor paint and varnish, and pigment caused the highest impact for indoor paint.
- The impacts during the use stage are significant for all three paint products, particularly the application of the coatings on the substrates, which relies on resource and energy consumption.
- The contribution of impacts during the product manufacturing stage (i.e., the factories where products are formulated) was low for all paint products and for all impact categories.
- The distribution stage contributed the least to environmental impacts for all paint products.
- Zinc sulphide is not a good alternative to titanium dioxide as white pigment from an environmental point of view, as it requires nearly double the amount of pigment to achieve the same opacity performance, resulting in overall higher environmental impacts.
- Paints containing preservatives have a better environmental performance than preservative-free paints. New and better preservation methods are needed to increase the lifetime and quality of the paint.

It is worth noting that these conclusions relate only to what can be measured in an LCA, and that some effects, especially on human health, are not captured by the LCA methodology.

4.4 Non-LCA impacts for paints and varnishes

Non-LCA impacts generally refers to effects on the environment and on human health that are not well captured or accurately quantified by current LCA methodology.

As per table B.3 of Commission Recommendation (EU) 2279/2021, the toxicity impact categories used in PEF methodology (i.e. human toxicity (carcinogenic), human toxicity (non-carcinogenic) and ecotoxicity) have a low degree of robustness (grade III) compared the other impact categories that are reported on (grades I or II).

There is an inherent need for LCA models to make simple and universally applicable rules and assumptions when calculating any environmental or health impacts. However, health impacts are far more complex and difficult to predict than the well-known physiochemical-based environmental impacts like acidification and global warming potential. This is because effects on the health of biological systems are very variable and depend greatly on real-life exposure. Chemical exposure scenario modelling is not something that LCA models are well suited to deal with, especially when involving many different chemicals at different life cycle stages – the model would quickly become enormously complex.

To compensate for the lack of robustness of LCA methodology for assessing human toxicity and ecotoxicity impacts, there is a need for background research to take another approach to assessing the impacts associated with hazardous substances in the production, use and disposal of paints and varnishes.

4.4.1 Hazard screening of ingredients used in paints and varnishes

A number of human health-related and environmental-related hazards have been established in the Global Harmonised System (GHS) of classification and labelling of chemicals. The same hazards have generally been applied in the EU via the Regulation (EC) No 1272/2008. Human health-related hazards fall within the H3XX hazard codes while environmental hazards fall within the H4XX codes. There are a number of other codes that only apply at EU level, and instead of starting with "H", they start with "EUH". The main hazards identified are:

- H315: Causes skin irritation.
- H317: May cause an allergic skin reaction.
- H319: Causes serious eye irritation.
- H350: May cause cancer.
- H351: Suspected of causing cancer.
- H400: Very toxic to aquatic life.
- H410: Very toxic to aquatic life with long lasting effects.

The list of EF datasets developed by CEPE was used as a de facto list of chemical ingredients for paints and varnishes and they have been searched in order to identify their CAS numbers and associated hazards. It should be noted that there are different levels of credibility that can apply with hazard classifications as follows:

- Harmonised → highest credibility
- Joint entry → medium credibility
- Self-classifications → lower credibility

In Annex 2, the chemicals are listed in alphabetical order, together with CAS numbers, links to the relevant ECHA substance info-card and the two most credible hazard classifications available (i.e. if harmonised, joint entry and self-classifications exist, only the harmonised and joint entry classifications are listed). If there are no harmonised classifications, or no joint entries, the term "none" is entered in the relevant cell.

4.4.1.1 Results of the hazard screening

Based on the information in Annex 2, a summary of the results of the hazard screening of substances known to be used in paints and varnished is presented in Table 52. The hazards identified have been divided into three categories – carcinogenic, toxic to human health and toxic to the environment.

Furthermore, the summary is split into whether the identified hazards were harmonised, joint entries or self-classifications in the ECHA C&L inventory. A total of 9 carcinogenic hazards have been identified in the harmonised classifications they are divided between 8 substances. The most common hazard code within human health is H315 and H319, which are causes skin irritation and serious eye irritation. With regards to environmental toxicity, one finds the hazard codes H400, H410 and H411, which are very toxic to aquatic life, very toxic to aquatic life with long lasting effects, and toxic to aquatic life with long lasting effects.

Table 52. Results from the hazard screening.

All substances – 81 in total				
Classification	Carcinogenic	Toxic		Environment
Harmonised	1x H340(1%), 3x H350(3%), 4x H351(5%), 1x H360D(1%),	4x H302(5%), 2x H304(2%), 8x H315(9%), 7x H317(8%), 2x H318(2%), 8x H319(9%),	2x H331(2%), 3x H332(3%), 1x H334(1%), 2x H335(2%), 1x H336(1%),	5x H400(6%), 5x H410(6%), 1x H411(1%),
Joint entry	2x H340(2%), 2x H341(2%), 3x H350(3%), 5x H351(6%), 3x H361(3%),	7x H302(8%), 2x H304(2%), 2x H314(2%), 10x H315(12%), 13x H317(15%), 4x H318(5%), 10x H319(12%),	2x H330(2%), 2x H331(2%), 4x H332(5%), 1x H334(1%), 4x H335(5%), 4x H336(5%), 1x H372(1%),	6x H400(7%), 7x H410(8%), 7x H411(8%), 2x H412(2%),

All substances – 81 in total				
Classification	Carcinogenic	Toxic		Environment
		1x H320(1%),	2x H373(2%),	
Self classification	1x H340(1%), 3x H350(3%), 3x H351(3%), 1x H361(1%),	6x H302(7%), 1x H304(1%), 1x H311(1%), 2x H312(2%), 11x H315(13%), 6x H317(7%), 5x H318(6%), 13x H319(15%), 1x H330(1%),	4x H332(5%), 1x H334(1%), 8x H335(9%), 3x H336(3%), 2x H370(2%), 4x H372(5%), 4x H373(5%), 1x H379(1%),	2x H400(2%), 2x H410(2%), 6x H411(7%), 3x H412(3%), 5x H413(6%),

Source: Own elaboration.

4.4.1.2 *A closer look at hazards with additives*

Of the 81 substances with CLP hazards, 8 substances on the assessed list of substances are categorized as additives. Table 53 gives an overview of this hazard classification of the 8 substances in the subcategory additives. It can be seen that one substance (benzophenone) is classified under H350 – may cause cancer. Additives also show toxicity hazards to human health. These are related to harmfulness when swallowed, eye damage and harmfulness when inhaled. Cuprous oxide and zinc phosphate are classified as very toxic to aquatic life with long lasting effects.

Three of the substances listed on the CEPE list could not be found in ECHAs C&L Classification register. These are:

- Copper acrylate
- Defoamer – product group
- Flouropolymer

These compounds or groups of compounds might be harmful for human health and the environment – especially the fluoropolymers, which are well known for their persistence and include PFAS. Within the assessed list of additives polysiloxane was not classified, hence not constituting a hazard.

Table 53. Overview of classification of additives used in paint.

Additives (8 substances)			
Classification	Carcinogenic	Toxicity	Environment
Harmonised	1x H350 (13%)	1x H302 (13%), 1x H318 (13%), 1x H332 (13%)	1x H400 (13%), 2x H410 (26%)
Joint entry	1x H350 (13%)	1x H318 (13%), 1x H332 (13%), 1x H373 (13%)	2x H410 (26%)
Self-classification	None	1x H315 (13%), 1x H138 (13%), 1x H319 (13%)	None

Source: Own elaboration.

4.4.1.3 *Binders and resins*

Binders and resins represent the largest subcategory within the list of compounds from the CEPE datasets used in paints and varnishes, accounting for 45 of the 81 substances with hazards. Table 54 presents an overview of the hazard codes relevant for binders and resins. The table shows entries within all three categories – carcinogenic, toxic to health and environmental hazards. The compounds classified as carcinogenic are:

- Ethylene vinyl acetate copolymer (H351 suspected of causing cancer, S)
- Irgacure 369 (H360d may cause damage to the unborn child, H)
- Trimethylolpropane triacrylate (H351 suspected of causing cancer, H, J)

— Vinyl acetate (H351 suspected of causing cancer, H, J)

Most entries regarding human health are related to skin irritation and eye irritation/damage. In total, 19 of the 45 binder and resin compounds were not classified in ECHAs C&L inventory and the following 6 compounds were not found:

— Alkyd dispersion
— Melamine methylated
— Polyurethane dispersion
— Pure acrylate dispersion
— Silicone resins
— Vinyl ester

Problems with finding chemicals stemmed from the fact that these listed substance groups had not been assigned a CAS number. It was not clear if they would eventually be assigned a CAS number one day or that they were exempt from REACH because of being considered as polymers.

Table 54. Overview of classification of binders and resins used in paint.

Binders and resins (45 substances)				
Classification	Carcinogenic	Toxicity		Environment
Harmonised	2x H351(4%), 1x H360D(2%),	5x H315(11%), 5x H317(11%), 5x H319(11%), 1x H331(2%),	1x H332(2%), 1x H334(2%), 2x H335(4%),	2x H400(4%), 2x H410(4%), 1x H411(2%),
Joint entries	2x H351(4%)	2x H302(4%), 2x H314(4%), 6x H315(13%), 9x H317(20%), 2x H318(4%), 6x H319(13%),	1x H320(2%), 1x H330(2%), 1x H331(2%), 1x H332(2%), 1x H334(2%), 2x H335(4%),	3x H400(7%), 3x H410(7%), 4x H411(9%), 1x H412(2%),
Self classification	1x H350(2%), 1x H351(2%),	2x H302(4%), 1x H311(2%), 2x H312(4%), 4x H315(9%),	4x H317(9%), 6x H319(13%), 3x H335(7%), 1x H336(2%),	3x H411(7%), 1x H412(2%), 4x H413(9%),

Source: Own elaboration.

4.4.1.4 Pigments

Pigments accounted for 10 of the substances on CEPE dataset for paints and varnishes. Table 55 gives an overview of the hazard classification of the subcategory pigments used in paints and varnishes. The hazard codes are related to 4 out of 10 pigments.

— Iron oxide, red pigment
— Iron oxide, yellow pigment
— Strontium chromate
— Titanium dioxide

The carcinogenic hazards are related to strontium chromate and titanium dioxide. Titanium dioxide is suspected to be carcinogenic, whereas strontium chromate may cause cancer (harmonised entry), is suspected of damaging fertility or the unborn child, and suspected of causing genetic defects (joint entry).

Five of the pigments are not classified in the ECHA C&L inventory. These are:

— Phthalocyanine blue
— Phthalocyanine green
— Pigment 13
— Pigment red 254
— Quinacridone pigment red 122

Information on CLP hazards for one pigment could not be found, which is Oxford grey pigment.

Table 55. Overview of classification of pigments used in paint.

Pigments (10 substances)			
Classification	Carcinogenic	Toxicity	Environment
Harmonised	1x H350 (10%), 1x H351 (10%),	1x H302 (10%),	1x H400 (10%), 1x H410 (10%),
Joint entries	1x H341 (10%), 1x H350 (10%), 1x H351 (10%), 1x H361 (10%),	1x H302 (10%), 1x H317 (10%), 1x H330 (10%), 1x H335 (10%),	1x H400 (10%), 1x H410 (10%),
Self classification	1x H350 (10%),	1x H302 (10%), 2x H315 (20%), 2x H318 (20%), 1x H319 (10%), 1x H332 (10%), 2x H335 (20%), 1x H336 (10%), 1x H370 (10%), 2x H372 (20%), 1x H373 (10%), 1x H379 (10%),	1x H400 (10%), 1x H410 (10%), 1x H411 (10%),

Source: Own elaboration.

4.4.2 A closer look at preservatives

Preservatives are used in paint and varnish to prevent microbial growth and fouling. The typical shelf life for paint products is 2 years, hence in-can preservation is needed. Only a few preservatives are suitable in paints to avoid skin sensitization. The most used substance group for preservatives in paint products is isothiazoline. Preservatives have the purpose of preventing microbial activities and therefore are toxic in their nature. Using less toxic chemicals as preservatives will result in higher amounts needed to achieve the same level of preservation. Alternatively, preservative paints are needed, however, this will most likely result in more paint wasted, imposing an environmental burden. Preservative free paints would require refrigerated storage to reduce microbial activity in the paint. Other measured to reduce the use of preservatives in paints could be:

- Ensuring anaerobic conditions in the paint can
- Powder paint where water is added by the consumer.
- Use of inorganic formulations
- Paint with high or low pH

4.4.3 A closer look at titanium dioxide

According to ECHAs C&L inventory TiO_2 is suspected to be carcinogenic and alternatives for the use of TiO_2 as pigment in paints are desired. TiO_2 is widely used as a pigment as it scatters visible light very efficiently. The scattering of light is measured as refractive index and for TiO_2 it is between 2,6 and 2,9 (Ruszala, 2015).

Some alternative pigments exist; however, their refractive index is lower compared to TiO_2.

- Zinc oxide – refractive index
- Kaolin – refractive index
- Calcium carbonate - refractive index
- Barium sulfate

The above-mentioned alternatives have a refractive index around 1,6. None of the above seems to be suitable for a complete substitution. However, some type of Kaolin can replace the amount of TiO_2 used by 20% (Ruszala, 2015) (Kasumba, et al., 2022).

The sensitivity analysis addressing the substitution of TiO_2 shows that reductions in the environmental impacts are seen for several impact categories (climate change, material use, human health carcinogenic, acidification and more) under the assumption that the substitution happens 1:1. However, as they do not have the same properties a 1:1 substitution is unlikely. In the sensitivity analysis TiO_2 was compared to ZnS and the results show that reductions are still seen if you use 30% more ZnS, but already at 50% increase the benefits are eliminated.

At the current state TiO_2 seems inevitable, however, one could restrict the amount of TiO_2 used in paints or require a certain amount of an alternative substance that can be used in combination with TiO_2.

4.4.4 A closer look at VOCs

One of the major environmental issues associated with paint and varnish products is the emission of VOCs. This group of compounds are well-known to contribute to the formation of ground level ozone formation, which is harmful to human health (European Commission, n.d.). The main source of VOCs tended to be from organic solvents and a shift from organic solvent to water-based paint and varnish formulations has greatly reduced VOC emissions in general. Exposure to VOCs has been reported to cause eye and skin irritation, together with other severe effects such as central nervous system effects and carcinogenicity. Especially in the context of indoor air quality, and in even more in modern buildings which tend to be more air-tight due to requirements for energy efficiency, there is a need to pay attention to sources of VOC emission.

Paints and varnishes are an important potential source of VOC emissions to indoor air, as are construction materials (e.g. laminate floors) and furniture (e.g. carpets, upholstered furniture and wood-based panels). While limits on total VOC content or total VOC emissions from paint films or other source materials are useful, an important point to bear in mind is that not all VOCs are equally harmful.

To this end, it is worth mentioning the revision of the Construction Products Regulation and work to date on a set of EU LCI values. The abbreviation “LCI” stands for “Lowest Concentration of Interest”, meaning the concentration at which emissions from a particular construction product should not be exceeded after 28 days testing in a chamber according to EN 16516. While the EU LCI values are not to be considered as targets for indoor air quality per se, the differences in the values reflect the level of toxicological concern with each individual VOC. As of December 2022, there were agreed EU LCI values for:

- 19 aromatic hydrocarbons, with values ranging from just 10 $\mu g/m^3$ for naphthalene to 2900 $\mu g/m^3$ for toluene.
- 6 saturated aliphatic hydrocarbons, with values ranging from 4300 µg/m3 for n-Hexane to 15000 $\mu g/m^3$ for n-Heptane.
- 5 terpenes, with values ranging from 1400 $\mu g/m^3$ for β-Pinene to 5000 $\mu g/m^3$ for Limonene.
- 11 aliphatic alcohols, with values ranging from 620 $\mu g/m^3$ for 2-Methyl-2-propanol (tert-Butanol) to 11000 $\mu g/m^3$ for 2-Methyl-1-propanol.
- 3 aromatic alcohols: phenol (70 $\mu g/m^3$), BHT (2,6-di-tert-butyl-4-methylphenol) (100 $\mu g/m^3$) and Benzyl alcohol (440 $\mu g/m^3$).
- 45 glycols/glycol ethers/glycol ethers, with values ranging from just 19 $\mu g/m^3$ for 1-Propylene glycol 2-methyl ether (2-methoxy-1-propanol) to 8700 $\mu g/m^3$ for Neopentyl glycol.
- 21 aldehydes, with values ranging from just 1 $\mu g/m^3$ for glutaraldehyde to 900 $\mu g/m^3$ for Hexanal, Heptanal, 2-Ethyl-hexanal, Octanal, Nonanal and Decanal.
- 10 ketones, with values ranging from 490 $\mu g/m^3$ for Acetophenone to 120000 for Acetone.
- 10 acids, with values ranging from 150 $\mu g/m^3$ for 2-Ethylhexanoic acid to 2100 $\mu g/m^3$ for n-Pentanoic acid (Valeric acid) and several other acids.
- 24 esters, with values ranging from just 10 $\mu g/m^3$ for Hexamethylene diacrylate to 8500 $\mu g/m^3$ for n-Butyl acetate.
- 2 chlorinated hydrocarbons: Tetrachloroethene (80 $\mu g/m^3$) and 1,4-Dichlorobenzene (150 $\mu g/m^3$).
- 17 “others”, with values ranging from just 1 $\mu g/m^3$ for 5-Chloro-2-methyl-2H-isothiazol-3-one (CMIT) to 116000 for Octamethylcyclotetrasiloxane (D4).

There are also a number of VOCs where work is ongoing to try and determine suitable EU LCI values. The list of EU LCI values should be considered as a dynamic list, where numbers can change as new toxicological data and new information on indoor air quality monitoring becomes available.

The compounds listed in the CEPE datasets and which were screened for CLP hazards were cross-checked against the “Agreed EU-LCI value” list from December 2022[135]. Table 56 shows the six compounds found on the EU-LCI list.

Table 56. List of compounds typically used in paints and varnishes found on the EU-LCI list.

Name	CAS no.	Ingredient category	LCI value [$\mu g/m^3$]
1,6-hexanediol diacrylate	13048-33-4	Binders / Resins	10

[135] See here: https://single-market-economy.ec.europa.eu/sectors/construction/eu-lci-subgroup/eu-lci-values_en

Name	CAS no.	Ingredient category	LCI value [µg/m³]
1-methoxy-2-propylacetate	108-65-6	Diluent / Solvent	650
2-butoxyethanol	111-76-2	Solvent	1600
Dipropylene glycol methyl ether	34590-94-8	Solvent	3100
Dipropylene glycol n-butyl ether	29911-28-2	Solvent	250
Methyl isobutyl ketone (4-methylpentan-2-one)	108-10-1	Solvent	1000

Source: Own elaboration.

Not surprisingly, the majority of the compounds in the table are solvents. The LCI values tell us that 1,6-hexanediol diacrylate is evaluated to be the most toxic compound, since it has an LCI value of 10 µg/m³. It is followed by dipropylene glycol n-butyl ether with a LCI value of 250 µg/m³.

Although not directly listed in the CEPE datasets, it is also worth highlighting the very low EU LCI value of 1 µg/m³ assigned to 5-Chloro-2-methyl-2H-isothiazol-3-one (CMIT) and the low value of 100 µg/m³ assigned to 2-Methyl-4-isothiazolin-3-one (MIT). These are two commonly used preservatives in paints and varnishes.

4.4.5 A closer look at microplastics

Microplastics are being detected almost ubiquitously across the world, including in very remote environments (Horton and Barnes, 2020)[136] and inside organisms, including humans (Jenner et al., 2022)[137].

Every year around 145 000 tonnes of microplastics are deliberately added to a range of products placed on the EU market including cosmetics or detergents, of which around 42 000 tonnes are intentionally added microplastics estimated to be released into the environment[138].

Due to the fact that polymers are generally not covered by the REACH Regulation (except for new REACH restriction as explained in next paragraph) and that they do not seem to exhibit any immediate toxic effects, the impacts of microplastics on human health and the environment are poorly understood and are not well captured in LCA methods and associated impact categories. For this reason, any concerns about microplastics fall in the non-LCA impacts section.

The EC brochure published in October 2023 as the "EU action against microplastics" summarises how microplastics are being targeted under the EU policy agenda. In this sense, the EU has developed a number of regulatory initiatives to prevent pollution coming from plastic products that end up in the environment and degrade there into microplastics, such as the Waste Framework Directive or the soon-to-be adopted Packaging and Packaging Waste Regulation[138]. Other policy instruments relevant to microplastics are the 2018 EU Plastic Strategy[139], 2020 New Circular Economy Action Plan announcing EU measures to tackle intentionally added and unintentionally released microplastics[140] and the 2021 Zero Pollution Action Plan confirming this ambition by setting a 30% reduction target in microplastics releases by 2030[141]. Macroplastic pollution is addressed by several pieces of legislation, such as the Single Use Plastics Directive[142], the Plastic Bags Directive[143] and the Policy Framework for Biobased, Biodegradable and Compostable Plastics[144]. All in all, these initiatives will help reduce the volumes of plastic arriving in the environment, thus reducing the generation of microplastics.

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136 Horton A.A. and Barnes D.K.A., 2020. Microplastic pollution in a rapidly changing world: Implications for remote and vulnerable marine ecosystems. Science of the Total Environment, Vol 738 (10), 140349. https://doi.org/10.1016/j.scitotenv.2020.140349

137 Jenner L.C., Rotchell J.M., Bennett R.T., Cowen M., Tentzeris V. and Sadofsky L.R., 2022. Detection of microplastics in human lung tissue using µFTIR spectroscopy. Science of the Total Environment, Vol 831, 154907. https://doi.org/10.1016/j.scitotenv.2022.154907

138 EU action against microplastics, brochure, 2023. Available at: https://op.europa.eu/en/publication-detail/-/publication/048dd075-6e47-11ee-9220-01aa75ed71a1

139 https://environment.ec.europa.eu/strategy/plastics-strategy_en

140 https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

141 https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en

142 https://environment.ec.europa.eu/topics/plastics/single-use-plastics_en

143 https://environment.ec.europa.eu/topics/plastics/plastic-bags_en

144 https://environment.ec.europa.eu/publications/communication-eu-policy-framework-biobased-biodegradable-and-compostable-plastics_en

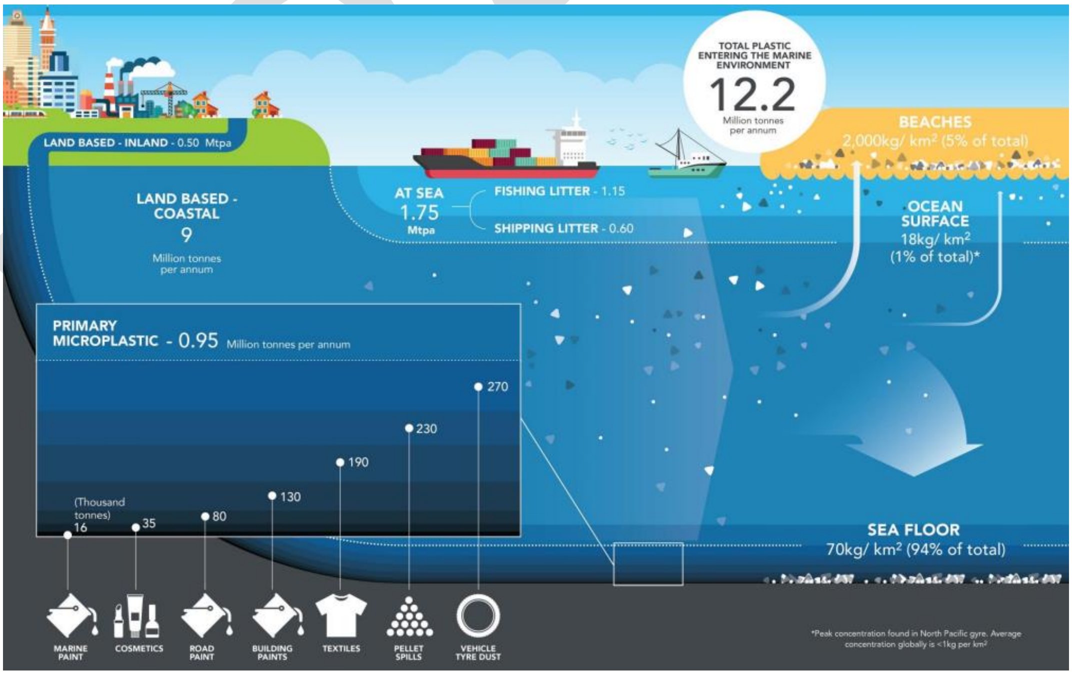
Moreover, the REACH restriction[145] on intentionally added microplastics adopted on 25.09.23 prohibits the sale of products containing intentionally-added microplastics and it covers all synthetic polymer particles below five millimetres that are organic, insoluble and resist degradation. The Commission has also proposed measures to prevent microplastic pollution from the unintentional release of plastic pellets[146], including best handling practices for operators, mandatory certification and self-declarations, a harmonised methodology to estimate losses and lighter requirements for SMEs (with a Commission proposal for a Regulation under discussion by the European Parliament and the Council).

It is important to make the distinction between microplastics that are actively added to products to impart certain properties – for example the use of microbeads in toothpaste to provide abrasive and exfoliating properties to the toothpaste – and microplastics that are generated due to wear and tear of polymeric materials (e.g. loss of paint films and tyre degradation).

As far as the authors are aware, the active addition of microplastics to decorative paint and varnish products is not a widespread practice, so the inclusion of such products could easily be excluded in EU Ecolabel criteria. However, the contribution of paints to microplastics entering watercourses (directly or indirectly) is generally considered to be highly significant, despite large variations in estimates.

At global level, a report by Eunomia (see infographic below) indicates that paints are an important source of primary microplastic flows that end up in oceans, accounting for around 130,000, 80,000 and 16,000 tonnes of primary microplastics from building paints, road paints and marine paints, respectively. In total, the microplastic emissions were around half of the 950,000 tonnes estimated. However, this must also be considered within the broader context of much higher levels (around 11,000,000 tonnes) of secondary microplastics coming from land-based litter and sea-based sources (where larger plastics enter then ocean and gradually break down into micro fragments). Paint products have however been identified as one of the major sources of unintentional microplastic releases to the environment by some authors[138, 147].

Figure 38. Infographic for microplastics flows and concentrations



Source: Eunomia report from 2016 titled: "Plastics in the marine environment".

[145] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4581

[146] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4984

[147] Mapping of Global Plastics Value Chain and Plastics Losses to the Environment: With a Particular Focus on Marine Environment, https://wedocs.unep.org/handle/20.500.11822/26745

A post on the World Economic Forum[148] suggested much higher contributions of paint to plastics, with a total of 1.5 to 2.25 million tonnes per year - around 20-30% of the estimated 8 million tonnes of microplastics estimated to enter oceans worldwide each year.

At European level, an article published by Turner (2021)[149] presented upper, middle and lower range estimates of microplastics to surface waters. In this case, middle range figures of 15,000, 5,000 and 400 tonnes per year were estimated for road paints, building paints and marine paints, respectively. These figures, as well as the upper and lower estimates, generally accounted for around 10-20% of total microplastic emissions. In these studies, it was understood that the emissions of microplastics from paints to the environment were founded upon the fact that most paint formulations are polymer-based (e.g. acrylics, alkyd, polyurethane, epoxy, polyester etc.) and that their emission was the result of physical wear and tear of painted surfaces, either during use or during the sanding of surfaces prior to the application of a new coating. Unless it was decided to ban the use of non-biodegradable synthetic polymers in the EU Ecolabel paints and varnishes, it is difficult to see how any measures could be defined for manufacturers to reduce the impacts of paint and varnish products on their contribution to microplastic pollution.

4.5 Improvement potentials

Biobased paint

As shown by the LCA screenings in section 4, the raw material stage leads to the most impacts for all three screened paint types. A possible way to decrease the environmental impacts in the raw materials stage is to shift to biobased paints, i.e. oleochemical raw materials, which may have a lower impact than the current petrochemical supply chains. However, in order to assess whether this indeed is an improvement to the overall environmental impact, access to primary data of such a paint would be necessary, both to get LCI data for the entire raw material phase, but also to ensure performance of the paint is comparable to the petrochemical baseline, and thus maintain the functional unit.

Value chain energy consumption

Since a lot of the raw material impact is related to energy consumption throughout the value chain, for producing the desired chemicals, a transition to renewable energy in all steps of the value chain, could also decrease the overall environmental impacts of the raw materials. To quantify the effect of this, would require a re-calculation of the background process for production of each of the raw materials in an LCA, and thus knowledge on specific energy needs for each step.

The impacts during the use stage were also shown by the LCA screenings to have significant impacts, especially the application. This is in large part due to the auxiliary materials needed for the painting process, i.e. brushes, rolls, coverage etc. The same potential for producing all of these with renewable energy and resources therefore exist.

These impacts throughout the value chain can, however, not be targeted directly through the EUEL criteria, but should be strategically decided upon by the raw material providers and paint producers.

Low or zero VOC paints

An increasing number of paints are marketed as “ultra-low VOC”, “zero VOC”, “No-VOC” and the like. It has not, however been possible to get specific definitions on these marketing terms, other than some indication that zero-VOC means less than 5 grams per litre[150] and low VOC means less than 50 grams per litre. It should be noted that these sources are all from the US. It is also not completely clear whether the “No-VOC” refers to the content of VOCs in the paints or is based on measurements on indoor air after application of the paint. One source suggests the latter, by referring to the Californian CDPH Standard Method for VOC Emissions (CDPH 01350)[151], in which VOCs are measured in the air 10-14 days after applying the paint.

It is also noted on one manufacturers website that “Fewer VOCs may result in a shorter lifespan for your paint, which means you may need to touch up low-VOC paint more often than other products.”[152]. As it has not been

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148 See here: https://www.weforum.org/agenda/2020/09/how-to-reduce-microplastics-from-paint/

149 Turner A. Paint particles in the marine environment: An overlooked component of microplastics. Water Research X. Vol. 12 (1), 100110. https://doi.org/10.1016/j.wroa.2021.100110

150 See: https://ecospaints.net/low-voc-paint-vs-no-voc-paint, https://robinsonpaintingllc.com/blog/whats-the-difference-between-voc-paint-and-no-voc-paint/#:~:text=Zero%2DVOC%20products%20contain%20few,of%20material%20harm%20to%20users.

151 See: https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/EHLB/AQS/Pages/VOCs.aspx

152 See:https://robinsonpaintingllc.com/blog/whats-the-difference-between-voc-paint-and-no-voc-paint/#:~:text=Zero%2DVOC%20products%20contain%20few,of%20material%20harm%20to%20users.

possible to find any specific formulations or durability tests of paints with these claims, it has not been possible to quantify the effect, or whether there is a trade-off in terms of higher maintenance (recoating). Due to the lack of formulations, it has also not been possible to assess how “zero VOC” is achieved, if it is for example only possible to obtain for mineral paints which have inherently lower contents of organic compounds, and thus VOCs.

Preservatives / biocide free paints

As seen from the simple sensitivity assessment in section 4.5, It is not clear cut whether biocide free paints are an overall improvement or not. While it is an improvement in terms of toxicity, the overall environmental impacts increase drastically in the case of biocide free paints, or paints without in-can preservatives due to increased spoilage rates. Hence, this is a trade-off between different impact categories, and a burden shifting from one impact type to another, which cannot be fully quantified. In order to improve the sensitivity assessment done in section 4.5.3, real-life statistics of spoilage rates for paints with and without preservatives/biocides would be necessary, and also the formulations of these paints.

4.5.1 Emerging best practices

Some improvement potentials are related to the practice of producers and how they sell their products. While most of the paint industry is quite uniform in this regard, a few emerging options could help improve the total environmental impact of paints.

One option, seen only in very small niche parts of the market, e.g. for artistic paints, is to sell only the dry parts of the paint, without water, and the end-user is then the ne mixing the paint before application, using tap water. This could potentially result in savings in the transportation and mixing processes, and perhaps most impactful, would results in less spoilage and the option to avoid preservatives, as the paint cannot spoil without water present. However, there might be some trade-offs related to final quality of the paint, due to e.g. the difficulty of uniform mixing, which requires high sheer force to separate the pigments, as described in previous section 4.1.3 about Paint Production (Water and Solvent-Based). It might also introduce the need for other, unknown additives such as anti-clumping agents, for which the environmental has not been analysed in the report.

Another market-based best practice could be extended producer responsibility in its most direct form, where paint manufacturers implement take-back schemes for unused paints from end-users / retail stores. While there may not yet be a use for the surplus paint residues, one could evolve when faced with the necessity, or at the very least the manufactures would be able to handle the surplus paints in the best way possible, given that they know the formulations, and which compounds it includes.

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List of abbreviations and definitions

AP	Acidification
BPR	Biocidal Products
CB	Competent Bodies
CC	Climate Change
CEPE	European Council of the Paint, Printing Ink, and Artist's Colours Industry
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
CPR	Construction Products Regulation
E-Fr	Eutrophication, freshwater
E-Ma	Eutrophication, marine
E-Te	Eutrophication, terrestrial
E-Tox	Ecotoxicity, freshwater
ECHA	European Chemicals Agency
EPD	Environmental Product Declaration
EF	Environmental Footprint
EFIA	Environmental Footprint Impact Assessment
EN	European Norm
ER	Resource depletion, fossil
ESPR	Ecodesign for Sustainable Products Regulation
EU	European Union
EUEB	European Union Ecolabelling Board
EUEL	European Union Ecolabel
GWP	Global Warming Potential
HTox-c	Human toxicity, cancer
HTox-nc	Human toxicity, non-cancer
IR	Ionising Radiation
ISO	International Organization for Standardization
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCS1	Raw material acquisition and pre-processing stage
LCS2	Manufacturing stage
LCS3	Distribution stage
LCS4	Use stage
LCS5	End-of-life stage
LU	Land Use
MR	Resource depletion, minerals & metals

NGO	Non-governmental Organization
OD	Ozone Depletion
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PM	Particulate Matter
POF	Photochemical Ozone Formation
PRODCOM	'PRODuction COMmunautaire' (Community Production)
PVC	Pigment Volume Concentration
VOC	Volatile Organic Compound
SVOCs	Semi-Volatile Organic Compounds
TiO_2	Titanium dioxide
WU	Water Use
ZnS	Zinc sulphide

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Annex 1 – List of relevant CLP hazards to screen for.

Table 57. List of human health-related and environmental-related hazard codes for chemicals.

Hazard class	Category	Hazard statement code	Hazard statement
Human health related			
Acute toxicity, oral	1, 2	H300	Fatal if swallowed
	3	H301	Toxic if swallowed
	4	H302	Harmful if swallowed
Acute toxicity, dermal	1, 2	H310	Fatal in contact with skin
	3	H311	Toxic in contact with skin
	4	H312	Harmful in contact with skin
Acute toxicity, inhalation	1, 2	H330	Fatal if inhaled
	3	H331	Toxic if inhaled
	4	H332	Harmful if inhaled
Aspiration hazard	1	H304	May be fatal if swallowed and enters airways
Skin corrosion / irritation	1A, 1B, 1C	H314	Causes severe skin burns and eye damage
	2	H315	Causes skin irritation
Serious eye damage / irritation	1	H318	Causes serious eye damage
	2	H319	Causes serious eye irritation
Respiratory sensitization	1	H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled
Skin sensitization	1, 1A, 1B	H317	May cause an allergic skin reaction
Mutagenicity	1A, 1B	H340	May cause genetic defects
	2	H341	Suspected of causing genetic defects
Carcinogenicity	1A, 1B	H350 (H350i)	May cause cancer May cause cancer if inhaled
	2	H351	Suspected of causing cancer
Reproductive toxicity	1A, 1B	H360 H360F H360D H360FD	May damage fertility or the unborn child May damage fertility May damage the unborn child May damage fertility. May damage the unborn child.
	2	H361 H361f H361d H361fd	Suspected of damaging fertility or the unborn child Suspected of damaging fertility Suspected of damaging the unborn child Suspected of damaging fertility. Suspected of damaging the unborn child.
Specific Target Organ Toxicity (single exposure)	1	H370	Causes damage to organs
	2	H371	May cause damage to organs
	1	H372	Causes damage to organs through prolonged or repeated exposure

Hazard class	Category	Hazard statement code	Hazard statement
Specific Target Organ Toxicity (repeated exposure)	2	H373	Causes damage to organs through prolonged or repeated exposure
Environmental hazards			
Hazardous to the aquatic environment, acute	1	H400	Very toxic to aquatic life
Hazardous to the aquatic environment, chronic	1	H410	Very toxic to aquatic life with long lasting effects
	2	H411	Toxic to aquatic life with long lasting effects
	3	H412	Harmful to aquatic life with long lasting effects
	4	H413	May cause long lasting harmful effects to aquatic life
Hazardous to the ozone layer	Ozone 1	H420	Harms public health and the environment by destroying ozone in the upper atmosphere
New harmonised hazard classes			
Endocrine disruption in humans	ED HH 1	EUH380	May cause endocrine disruption in humans
	ED HH 2	EUH381	Suspected of causing endocrine disruption in humans
Endocrine disruption in the environment	ED ENV 1	EUH430	May cause endocrine disruption in the environment
	ED ENV 2	EUH431	Suspected of causing endocrine disruption in the environment
Persistence and bioaccumulation	PBT	EUH440	Accumulates in the environment and living organisms, including in humans
	VPvB	EUH441	Strongly accumulates in the environment and living organisms, including in humans
Persistence and mobility	PMT	EUH450	Can cause long-lasting and diffuse contamination of water resources
	vPvM	EUH451	Can cause very long-lasting and diffuse contamination of water resources

Source: Own elaboration.

Annex 2 – Results of the hazard screening.

Table 58. CEPEs list of substances with their CAS no. and appertaining hazard classification.

The codes in red are hazard codes related to carcinogenic hazards and orange are the other codes that are restricted by the EUEL.

Name	CAS no.	Ingredient category	Link to ECHA	Harmonised	Joint entry	Self-classification
1,6-hexanediol diacrylate	13048-33-4	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/107281	H315, H319, H317	H315, H317, H319, H400, H411	
1-methoxy-2-propylacetate	108-65-6	Diluent / Solvent	https://echa.europa.eu/lt/information-on-chemicals/cl-inventory-database/-/discli/details/128608	H226	H226, H336	
2-butoxyethanol	111-76-2	Solvent	https://echa.europa.eu/lv/information-on-chemicals/cl-inventory-database/-/discli/details/129381	H302, H315, H319, H331	H302, H315, H319, H331	
Acetyl tributyl citrate	77-90-7	Softener	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/111970	none	none	H412, H220, H340, H350, H319, H315, H411, H413, H226

Name	CAS no.	Ingredient category	Link to ECHA	Harmonised	Joint entry	Self-classification
Acrylate binder	27599-56-0	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/214654	none	none	H315, H319, H335, H336
Acrylic resin	9065-11-6	Binders / Resins	No entry			
Alkyd dispersion	N/A	Binders / Resins	N/A	N/A	N/A	N/A
Alkyd resin	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (coconut oil)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (short oil)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (soya oil)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (sunflower oil)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (thixotropic polyamide)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (thixotropic polyurethane)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (TOFA)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin (urethane modified)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin dispersion (ext emulsified)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Alkyd resin dispersion (self-emulsified)	67989-61-1	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/122642	Not classified		
Amine modified acrylates	188012-57-9	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/28579	none	none	H317, H319, H412, H335
Anhydride hardener	N/A	Crosslinker and Binder for Epoxy	N/A	N/A	N/A	N/A
Aromatic hydrocarbons, C8-C10	64742-95-6	Diluent / Solvent	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/50391	H304, H340, H350	H304, H340, H350, H224, H315, H336, H361, H411, H226, H225	

Name	CAS no.	Ingredient category	Link to ECHA	Harmonised	Joint entry	Self-classification
Aromatic hydrocarbons, C9-C16	64742-94-5	Diluent / Solvent	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/48567	H304	H304, H315, H351, H411, H336, H226, H350, H225, H319, H335, H302, H332, H340, H361, H372, H410, H361d, H373, H412, H317, H371, H341	
Bentonite thickeners	1302-78-9	Rheology modifier	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/116081	none	none	H302, H315, H317, H319, H332, H334, H335, H351, H370, H371, H372, H373
Benzisothiazolinone (1,2-benzisothiazolin-3-one)	2634-33-5	Biocide	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/53588	H302, H315, H318, H317, H400	H302, H315, H318, H317, H400, H411	
Benzoguanamine formaldehyde butylated	68002-26-6	Binder for enamels	https://echa.europa.eu/da/substance-information/-/substanceinfo/100.120.009	none	none	H411, H413
Benzophenone	119-61-9	Additive: UV-stabilizer	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/11729	H350	H373	
Calcium aluminate cement	12042-68-1	Additive: Dryer	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/60062	none	none	H315, H318, H319, H332
Cellulose aceto butyrate	9004-36-8	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/121162	none	none	H312, H302, H315, H319, H335
Chlorinated rubber (unspecified)	9006-03-5	Binders / Resins	https://echa.europa.eu/de/information-on-chemicals/cl-inventory-database/-/discli/details/86183	Not classified		
Copper acrylate	13991-90-7	Additive: catalyst	N/A	N/A	N/A	N/A
Cuprous oxide	1317-39-1	Additive	https://echa.europa.eu/de/information-on-chemicals/cl-inventory-database/-/discli/details/90461	H302, H318, H332, H410	H302, H318, H332, H410	
Defoamer (BYK-012)	N/A	Additive	N/A	N/A	N/A	N/A
Diatomite (diatomaceous silica), dried	61790-53-2	Filler	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/79375	none	none	H315, H319, H335, H351, H372, H373

Name	CAS no.	Ingredient category	Link to ECHA	Harmonised	Joint entry	Self-classification
Diatomite (diatomaceous silica), not dried		Filler	Same as above			
Dibasic esters (unspecified)	95481-62-2	Solvent	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/84714	none	none	H302
Dipropylene glycol diacrylate	57472-68-1	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/1092	none	H315, H317, H318	H302, H315, H317, H318, H319, H335, H412
Dipropylene glycol methyl ether	34590-94-8	Solvent	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/6538	none	none	H226, H302, H304, H315, H317, H318, H319, H335, H336, H361, H373, H400, H410, H411, H412
Dipropylene glycol n-butyl ether	29911-28-2	Solvent	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/91683	none	none	H319, H318, H330, H332
Epoxy liquid, from Bisphenol A	25068-38-6	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/45750	H315, H319, H317, H411	H315, H317, H319, H411	
Epoxy liquid, from Bisphenol A	1675-54-3	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/97651	H315, H319, H317	H315, H317, H319, H411	
Epoxy liquid, from Bisphenol F	9003-36-5	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/86906	none	none	H311, H315, H317, H319, H411, H413
Epoxy semi solid, from Bisphenol A		Binders / Resins	Same as Epoxy liquid, from Bisphenol A			
Epoxy semi solid, from Bisphenol A		Binders / Resins	Same as Epoxy liquid, from Bisphenol A			
Epoxy solid, from Bisphenol A		Binders / Resins	Same as Epoxy liquid, from Bisphenol A			
Epoxy solid, from Bisphenol F		Binders / Resins	Same as Epoxy liquid, from Bisphenol A			
Epoxy waterborne, from Bisphenol A		Binders / Resins	Same as Epoxy liquid, from Bisphenol A			
Epoxyacrylate	55818-57-0	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/10952	none	H317, H411	H315, H317, H319, H335, H411, H413
Ethoxylated trimethylolpropane triacrylate	28961-43-5	Binders / Resins		Not classified		

Name	CAS no.	Ingredient category	Link to ECHA	Harmonised	Joint entry	Self-classification
Ethylene vinyl acetate copolymer	24937-78-8	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/132545	none	none	H317, H351, H315, H319
Fluoropolymer, unspecified	N/A	Additive: Tensid (sufractant)	N/A	N/A	N/A	N/A
Glycerol, propoxylated, esters with acrylic acid	52408-84-1	Softener	https://www.echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database/-/discli/details/114763	none	H317, H319	H315, H317, H319, H335, H361f, H373, H400, H411, H412
Gypsum plaster	13397-24-5	Filler		Not classified		
Hexamethylene diisocyanate	822-06-0	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/130293	H315, H319, H317, H331, H335, H334	H302, H314, H315, H317, H319, H330, H331, H334, H335	
Hydroxypropyl methacrylate	27813-02-1	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/124725		H317, H319, H320	
Irgacure 369	119313-12-1	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/86984	H400, H410, H360D	H410	
Iron oxide, red pigment	1309-37-1	Pigments	https://echa.europa.eu/lt/information-on-chemicals/cl-inventory-database/-/discli/details/18003	none	none	H302, H315, H318, H319, H332, H335, H336, H350, H370, H372, H373, H379, H400, H410, H411
Iron oxide, yellow pigment	51274-00-1	Pigments	https://echa.europa.eu/lv/information-on-chemicals/cl-inventory-database/-/discli/details/82237	none	none	H315, H318, H335, H372
Melamine formaldehyde butylated	68002-25-5	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/69093	none	none	H413, H226, H411, H312, H302, H317, H350
Melamine methylated	N/A	Binders / Resins	N/A	N/A	N/A	N/A
Methyl isobutyl ketone (4-methylpentan-2-one)	108-10-1	Solvent	https://echa.europa.eu/cs/information-on-chemicals/cl-inventory-database/-/discli/details/71683	H225, H319, H332, H336, H351	H225, H319, H332, H336, H351	
Nitrocellulose	9004-70-0	Binders / Resins	https://echa.europa.eu/nl/information-on-chemicals/cl-inventory-database/-/discli/details/65845	none	none	H228, H201, H225, H413, H319

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Oxford grey pigment, pulverised form	N/A	Pigments	N/A	N/A	N/A	N/A
Pentaerythritol triacrylate	3524-68-3	Cross-linker / Binder	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/70855	H315, H319, H317		
Phthalocyanine blue	147-14-8	Pigment	https://echa.europa.eu/da/substance-information/-/substanceinfo/100.005.169	Not classified		
Phthalocyanine green	14832-14-5	Pigment	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/80028	Not classified		
Pigment 13	5102-83-0	Pigment	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/19587	Not classified		
Pigment red 254	84632-65-5	Pigment	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/35576	Not classified		
Pliolite acrylic copolymer resin	9010-92-8	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/104218	Not classified		
Polyisocyanate	81217-97-2	Binders / Resins	https://echa.europa.eu/da/substance-information/-/substanceinfo/100.238.716	Not classified		
Polypropylene glycol	25322-69-4	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/43615	Not classified		
Polysiloxane	161755-53-9	Additive	https://echa.europa.eu/da/substance-information/-/substanceinfo/100.132.435	Not classified		
Polyurethane dispersion	N/A	Binders / Resins	N/A	N/A	N/A	N/A
Pure acrylate dispersion	N/A	Binders / Resins	N/A	N/A	N/A	N/A
Quinacridone pigment red 122	980-26-7	Pigment	https://echa.europa.eu/da/substance-information/-/substanceinfo/100.012.329	Not classified		
Silica (silicone dioxide)	7631-86-9	Filler	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/50736	Not classified		
Silicone resins	N/A	Binders / Resins	N/A	N/A	N/A	N/A
Strontium chromate	7789-06-2	Pigment	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/53759	H302, H350, H400, H410	H302, H317, H330, H335, H341, H350, H361, H400, H410	
Styrene acrylate dispersion	60806-47-5	Binders / Resins	https://echa.europa.eu/da/substance-information/-/substanceinfo/100.346.320	Not classified		
Styrene butadiene dispersion	9003-55-8	Binders / Resins		Not classified		

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Titanium dioxide	13463-67-7	Pigment	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/100661	H351	H351	
Trimethylolpropane triacrylate	15625-89-5	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/13663	H315, H319, H317, H351, H400, H410	H315, H319, H317, H351, H400, H410	
Vinyl acetate dispersion	108-05-4	Binders / Resins	https://echa.europa.eu/da/substance-information/-/substanceinfo/100.003.224	H225, H332, H335, H351	H225, H332, H335, H351, H412	
Vinyl acetate ethylene dispersion	24937-78-8	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/13338	Not classified		
Vinyl ester	N/A	Binders / Resins	N/A	N/A	N/A	N/A
Zinc acrylate	14643-87-9	Binders / Resins	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/20341		H302, H314, H317, H318, H400, H410	
Zinc phosphate	7779-90-0	Additive: anti-corrosion	https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database/-/discli/details/125118	H400, H410	H400, H410	

Source: Own elaboration.

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