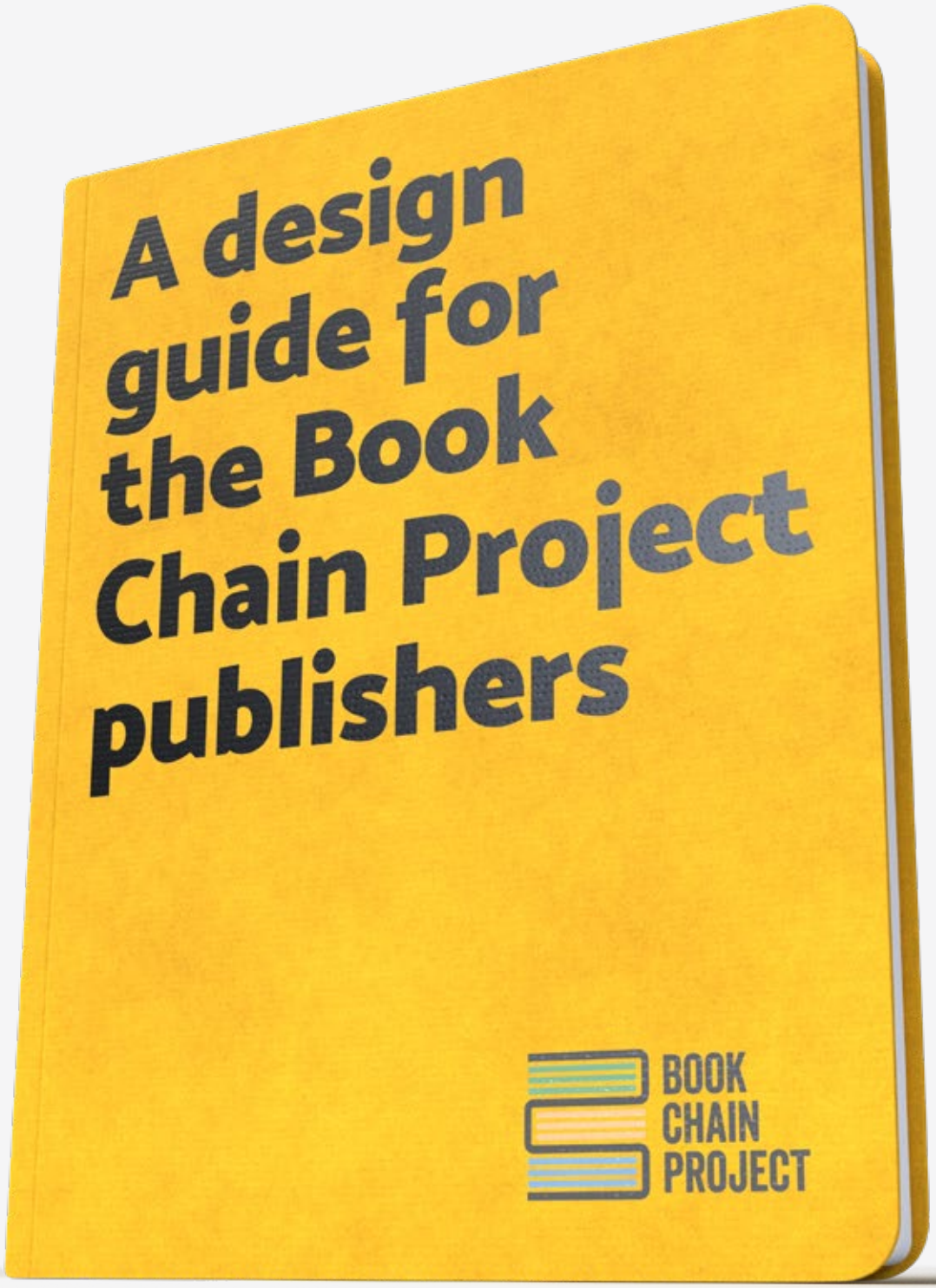

CO_2e

Updated to include Emissions factors

BOOK CHAIN PROJECT

About the Book Chain Project

The Book Chain Project is a collaborative initiative run by Carnstone. We involve 28 leading book and journal publishers, over 400 print suppliers and more than 300 paper manufacturers.

We have been making sense of complex publisher supply chains since 2006 – collecting and analysing data, providing guidance and bringing together different stakeholders in order to assess and reduce supply chain impact. We are here to enable publishers to make informed decisions about all stages of book production.

Originally three different workstreams, PREPS, PIPS and PRELIMS became a single platform in 2016, called the Book Chain Project.

The publishers participating in the Book Chain project have one common aspiration – to make informed buying decisions and minimise the impact their books have on the environment, as well as those who manufacture or read their books. To this effect, the Book Chain Project collects information from the book supply chain including:

- Print site locations, audit results, and environmental credentials
- Inventory of products (i.e. components) used to produce the books.
- Chemical substances per component, screened against safety legislation.
- Tree species and country of origin of each fibre used in paper and boards.

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ABOUT CARNSTONE

Carnstone is a management consultancy specialising in sustainability and corporate responsibility in conjunction with business strategy. We work across a number of different industries and provide advice and support to international organisations, NGOs and companies from offices in London and Shanghai.

carnstone.com / @Carnstone

Carnstone

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Introduction

'Design for Sustainability' has been a growing concept in the last few years, showing a clear shift from solely mitigating environmental and social impacts with end-of-pipe solutions, such as interventions at process level within a supply chain, to a more rounded approach including actions contributing to prevention in the first place of these impacts. By adopting this more holistic life-cycle perspective, there is an opportunity to make design decisions which will seek to **reduce or prevent the negative environmental and social impacts caused in the manufacture of books, magazines and journals.**

As a collective project, the Book Chain Project aims to give publishers the tools they need to make informed decisions. One area we had yet to explore in detail was around how design decisions can embed sustainability challenges upstream in the supply chain. How a book is designed determines what materials a book is made from and the processes used to make the book. In turn, this can impact the lifecycle of the book in the future. As the circular economy comes to the forefront of sustainability it is more important than ever to understand the lifecycle of a book, in order to work towards the publishing industry becoming a closed loop.

It is vital for the industry to understand the trade-offs between designing a product with a long shelf life and designing for sustainability.

The aim of this report is to show the environmental and social impacts of the different materials used as well as the different processes involved in making a book. In keeping with the aims of the Book Chain Project, we've developed this guide to help the publishers, and more specifically the different actors involved in the design decision making process (see process diagram on page 6), to make informed decisions on the different materials and/or processes required to make a book.

It is important to bear in mind that this industry is making products that are made to last for many years and durability is an important, and often undervalued tenet of the circular economy. Books are not created to be single-use, they are made to be read and passed on again and again, whether fiction or non-fiction, academic or chick-lit. It is vital for the industry to understand the trade-offs between designing a product with a long shelf life and designing for sustainability. There will be a different balance to be found for every book and every publisher – it's important that we don't lose sight of the original function of a book. They are here to transport the reader somewhere new, whether to learn, dream or escape, and these are things that we just can't include in a guide like this.

The information contained in this guide is accurate about the materials and processes in isolation, but it does not take the wider context of their use into consideration – as the publishers, the guide is here to enable you to make informed decisions about what that book is going to be made of.

WHAT DID WE DO?

We started by interviewing publishers and printers to broaden our understanding of the design process at publishing houses and to draw a list of the materials most commonly used, and the different manufacturing processes undertaken. We then completed any gaps in the information collected with desk-based research for each material/process to better understand 1) their environmental impact, 2) their recyclable properties, and 3) their health and safety and labour risks.

WHAT DO THE DIFFERENT COLOURS MEAN?

We have given each material and process a 'score' – red (high risk), amber (medium risk) and green (low-risk) on three different matrices – the environment, health and safety / labour, and recyclability. Each material and process is also given an overall score, based on the highest risk score given to a category. We focus on local environmental and health and safey / labour issues unless otherwise specified. In addition, we look at the recyclability of each individual component. We cannot make reference to the recyclability of a finished book without understanding what it is made of.

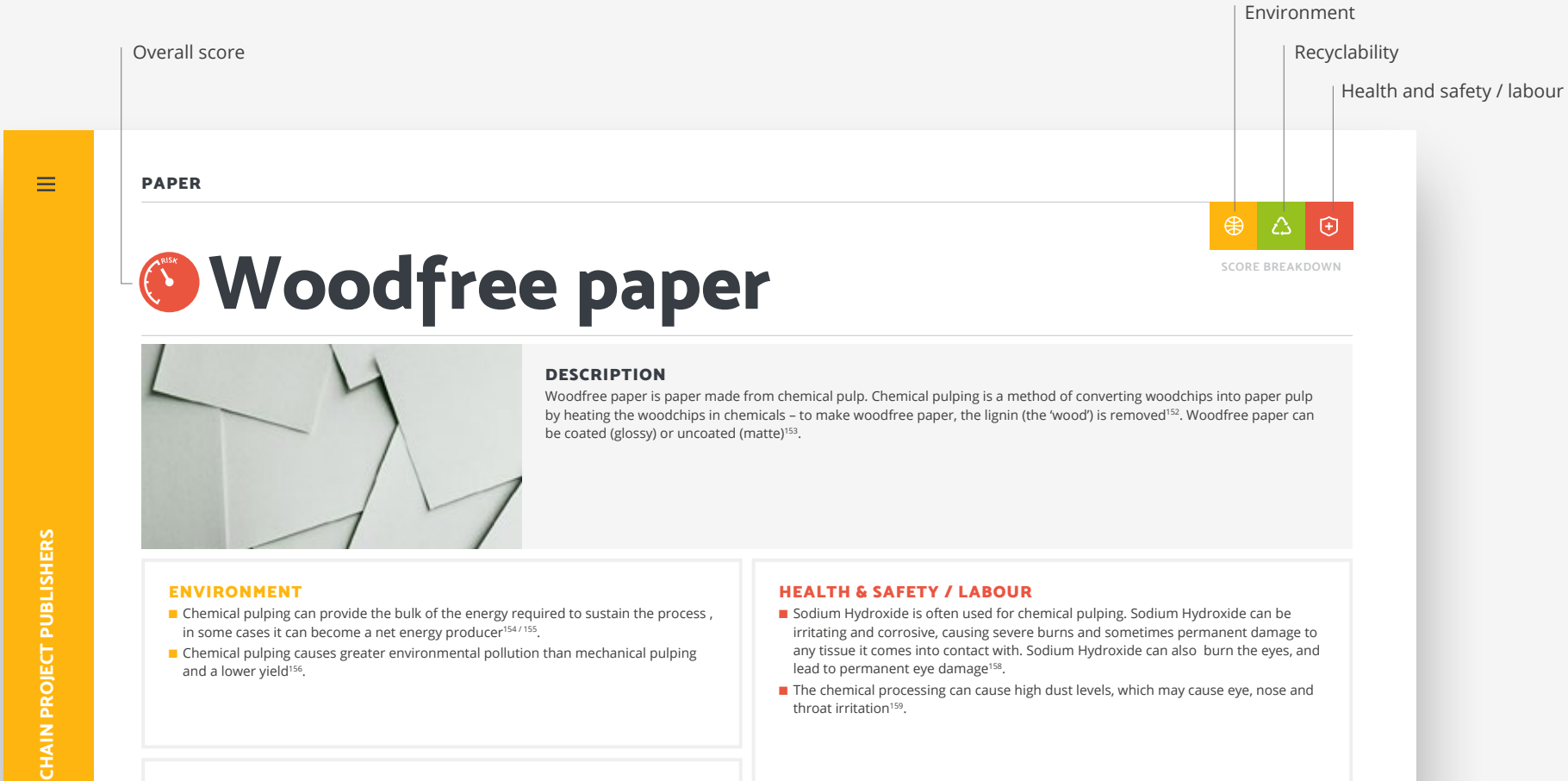
IF A PROCESS HAS BEEN SCORED RED, DOES THAT MEAN I SHOULDN'T USE IT?

No. This guide is not here to tell you which materials and processes you should and should not use. It is here to give you the tools to understand further about each material and process, in order to make an informed decision.

WHAT IS THE BEST WAY TO READ THE GUIDE?

We have created this guide as a PDF with clickable links to enable users to navigate the document in a number of different ways. Recognising that some people will not want to sit and read the whole document, the contents page allows you to click on a relevant material or process and go straight to the relevant page. If the alternative suggested on a material page is contained in the guide, it will be shown in bold so you will be able to click through and read further about the alternative.

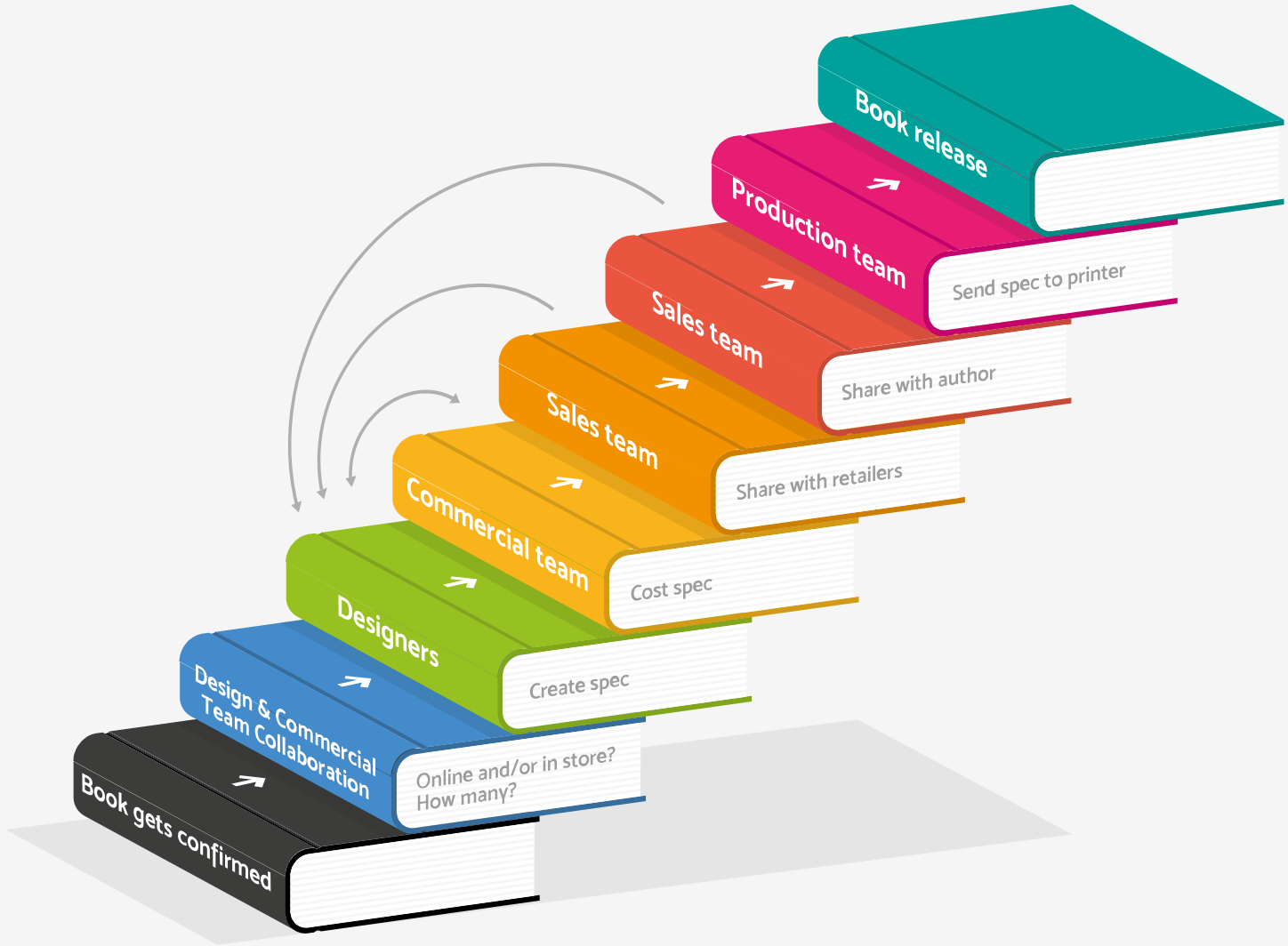
The guide is also perfect to print off and have as a reference on your desk, to be used at any point during the design-making process.



Contents

Design process diagram

Using the knowledge gained from our interviews with publishers and suppliers, we created a design process diagram showing the common actions across different publishing houses. The Design Guide has been created to assist all actors across the design process, allowing everyone to make informed choices on the spec of the publication.



Varnish

SCORE BREAKDOWN

3.264KG CO_2e per kg of varnish[1]

DESCRIPTION

Varnish is a liquid coating applied to a printed surface for protection and appearance[2]. It protects the page from scuffing, rubbing, smearing and wear and it tends to be a low-cost option[3]. It can also be used to make an aesthetic contribution by emphasising details in photos or logos – varnish can be clear or tinted, matte or glossy, and different styles of varnish can be used together for higher impact[4]. It can be done in a 'spot' finish, on just a small section of a page, or it can be done across the whole page, in a 'flood'[5]. This page is based on traditional, oil based varnish.

ENVIRONMENT

- Traditional varnish has a petroleum-base and therefore is a by-product of crude oil. Mining for crude oil can cause a number of environmental issues, such as air pollution and contributing to greenhouse gases[6] These types of plastic also usually contain volatile organic compounds - VOCs[7].
- During the during process, VOCs in the form of toxic fumes can enter the atmosphere and contribute to air pollution[8].

RECYCLABILITY

- Varnish can be difficult to recycle, but it is possible and regularly done in the printing industry. It should be collected by a licensed contractor and disposed of at a qualified treatment facility. Residual solvent-based varnish is highly flammable and needs to be treated accordingly[9]. However, if the coating weight of varnish is over 2.5gsm it becomes significantly more difficult to recycle as most recycling centres will not be able to break it down.

HEALTH & SAFETY / LABOUR

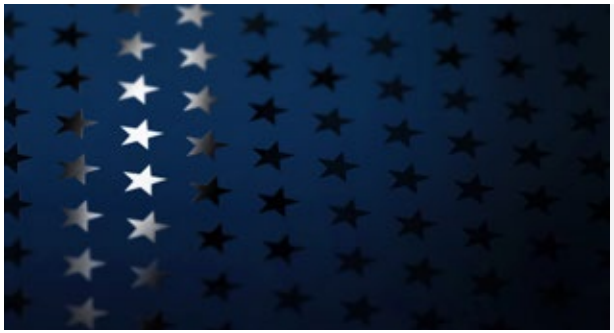
- As varnish often contains petroleum or other hazardous materials (and therefore is highly flammable), great care must be taken to ensure employees are trained in waste management and health and safety. Users must wear facemasks, eye protection and have adequate ventilation during application[10].
- Varnish often contains VOCs, which are known irritants to the skin, eyes, lungs and throat. They can contribute to neurological damage and birth defects, and some are also carcinogens[11]. These can be released in the form of toxic fumes during the drying process.
- VOCs are carefully legislated in the EU[12], but this is not the case in some parts of Asia, including China (although legislation is slowly being developed)[13].

ALTERNATIVES

- **UV varnish:** When cured (with light and not heat, unlike oil-based varnish), UV inks or varnishes don't contain any solvents, oils or hazardous volatile compounds. There has been much development in recent years, so now UV varnish is recyclable[14]. It can be a more expensive option[15].
- Water-based / aqueous coatings: Water based varnish contains minimal VOCs, so are safer for the environment and workers' health. They are also easily recyclable. However, they are not as shiny as their counterparts, so some perceive them as lower quality[16].

UV Varnish

SCORE BREAKDOWN



DESCRIPTION

UV varnish is a clear liquid applied to paper and cured with exposure to a UV light[17]. It can be applied over the entire page in a 'flood' manner, or just across specific parts of the page, in a 'spot'[18]. It can be used for both decorative purposes – to create designs or highlight parts of a page – and as a separate finishing operation (for both protection and design), making it a viable alternative to lamination or traditional varnish[19]. UV varnish can crack if applied over a fold, so care is necessary during application[20]. UV varnish is more effective at protecting pages than traditional varnish, and can also have a glossier finish[21].

ENVIRONMENT

- UV coatings dry almost instantly, meaning the printing turnaround time can be reduced by up to 40% in comparison to traditional varnish, reducing overall energy consumption[22]. Although energy consumption in this process can be high, it is also efficient. This is a trade-off that needs to be assessed and managed by each individual business.
- UV coatings do contain volatile organic compounds (VOCs) which can be harmful to both the environment and people. VOCs contribute towards air pollution and therefore can be damaging to the planet. However, as UV varnish is cured using light and not heat, the VOCs are not released into the atmosphere[23].

RECYCLABILITY

- UV varnish has developed significantly over the past few years. It is now recyclable with 'mixed waste', although it is more difficult to recycle than standard varnish[24].

HEALTH & SAFETY / LABOUR

- UV varnish consists of acrylic polymers derived from crude oil, which are created using highly toxic substances, called VOCs[25]. VOCs are harmful to both the environment and people, hence them appearing across both boxes.
- VOCs are known irritants to the skin, eyes, lungs and throat. They can contribute to neurological damage and birth defects, and some are also carcinogens[26]. The release of VOCs should be avoided in UV varnish as it is cured using light, not heat. However, there is still a small risk of accidents occurring and workers being exposed to VOCs.
- Exposure to UV radiation can cause acute, abnormal redness on skin. Continued exposure, even at low doses can cause a severe reaction[27].
- Exposure to UV light can cause serious burns to the cornea in the eye. It is also associated with cataract formation and retinal damage – it is vital that workers wear adequate eye protection[28].

ALTERNATIVES

- Water-based / aqueous coatings: Water based varnish contains minimal VOCs, so are safer for the environment and workers' health. They are also easily recyclable, as an uncoated paper would be. However, they are not as shiny as their counterparts, so some believe they appear to be of lower quality[29].
- **Varnish**

Laminate

SCORE BREAKDOWN

3.146KG CO_2e per kg of laminate[30]

(Material assumed to be polypropylene)

DESCRIPTION

Laminates can come in a sheet-form or as a liquid[31]. A sheet of clear plastic film is laid over the paper in one method or a clear liquid is spread over the sheet and cured like a varnish in another[32]. Various different forms of plastic can be used as laminate – the most common are PET, PVC, PE and EVA[33]. Laminates are extremely durable and can offer the greatest protection for paper. However they are heavier than other options, and take longer to produce so don't tend to be suitable for large press runs[34]. Some laminate can also become unstable over time, breaking down the paper and causing it to become discoloured and brittle[35].

ENVIRONMENT

- Most laminates are manufactured using petroleum-based plastics and are therefore a by-product of crude oil. Mining for crude oil can cause a number of environmental issues, such as air pollution and contributing to greenhouse gases[36]. These types of plastic also usually contain volatile organic compounds - VOCs[37].
- VOCs can be harmful to both the environment and people. VOCs contribute towards air pollution and therefore can be damaging to the planet[38].

RECYCLABILITY

- Laminate can be made of various types of plastic including PET, PVC and PE. When these plastics are bound to paper as laminate, it renders them both non-recyclable.[39 / 40].

HEALTH & SAFETY / LABOUR

- Laminates can contain volatile organic compounds (VOCs) such as formaldehyde[41], which is classified as a human carcinogen[42]. VOCs are harmful to both the environment and people, hence them appearing across both sections. These toxic fumes (VOCs) can be released when liquid laminate is cured, causing potential issues for the workers laminating[43].
- VOCs are known irritants to the skin, eyes, lungs and throat. They can contribute to neurological damage and birth defects, and some, as above, are also carcinogens[44].
- As per the environment section, most laminates are manufactured using petroleum-based plastics created from crude oil. Environmental issues and health issues often go hand-in-hand, particularly when it comes to pollution. Air pollution damages natural ecosystems and can be detrimental to human health, particularly the respiratory system[45].

ALTERNATIVES

- **UV varnish**
- **Varnish**

- Water-based / aqueous coatings: Water based varnish contains minimal VOCs, so are safer for the environment and workers' health. They are also easily recyclable, as an uncoated paper would be. However, they are not as shiny as their counterparts, so some believe they appear to be of lower quality[46].
- Cellulose based varnish. Cellulose is biodegradable and compostable[47].

Ink [solvent-based]

SCORE BREAKDOWN

3.264KG CO_2e per kg of ink[48]

(Generalised emissions factor for all ink types)

DESCRIPTION

Ink has three basic components: a vehicle, a pigment and a drier[49]. The vehicle can be several different things: traditionally it has been solvent-based, although it can also be **water** or **oil-based**[50]. These different types of ink can also be referred to as evaporation-drying ink (solvent), oxidation-drying ink (oil), and precipitation-drying ink (water)[51]. For simplicity's sake, within this document we have referred to them as **solvent-based**, **oil-based** and **water-based** inks. This section focuses on traditional, solvent-based ink. You can find alternatives in **Ink (alternatives)**.

ENVIRONMENT

- Solvent-based inks contain volatile organic compounds (VOCs). VOCs are a large family of carbon-containing compounds with varying safety, fire, health and environmental risks, released as toxic fumes[52]. VOCs contribute to air pollution[53].
- Most solvent-based inks contain organic pigments that are insoluble and not easily biodegradable[54]. They can also contain heavy metallic pigments that can accumulate in the soil or leach into groundwater systems, impacting biodiversity and ecosystem health[55]. These pigments are closely controlled in the EU, however they are not in parts of Asia, including China[56].

RECYCLABILITY

- Inks are recyclable under controlled conditions[57 / 58].

HEALTH & SAFETY / LABOUR

- Solvent-based inks contain VOCs in the form of toxic fumes. VOCs can be carcinogenic and pose damage to the central nervous system[59]. VOCs are irritants to the skin, eyes, lungs and throat[60].
- The solvents in inks can irritate the skin leading to dermatitis, skin allergies and asthma. The vapours can also make workers dizzy, drowsy, and damage internal organs if exposure is over a long period of time[61 / 62].
- Regulations against solvent-based inks due to their volatile organic compounds are increasingly coming into force, although these have not yet reached key manufacturing markets such as China[63].

ALTERNATIVES

- **Oil-based ink**
- **Water-based ink**
- **UV / Electronic Beam ink**
- Algae ink – ink products grown from algae. These inks are biodegradable.[64]

3.264KG CO_2e per kg of ink[65]
(Generalised emissions factor for all ink types)

Water-based ink

SCORE BREAKDOWN

DESCRIPTION

Ink that uses water as its main vehicle. All inks have three main components: a vehicle, a pigment and a drier[66].

ENVIRONMENT

- Most water-based inks use a biodegradable polymer called PHA instead of petroleum-based solvents, eliminating volatile organic compounds[67 / 68].
- Can be energy intensive, as more heat is needed to dry and cure the ink[69].

RECYCLABILITY

- Inks are recyclable under controlled conditions. This does not change if they are water based – they must still go to a specialist facility[70 / 71].

HEALTH & SAFETY / LABOUR

- Ensure the ink does not contain solvents (some inks use both water and solvents as vehicles), as the inhalation of harmful volatile organic compounds (toxic fumes) remains a risk[72].

Oil-based ink

SCORE BREAKDOWN

DESCRIPTION

Ink that uses oil as its main vehicle. All inks have three main components: a vehicle, a pigment and a drier[73]. The vehicles used in oil-based inks are normally linseed, vegetable or soy.

ENVIRONMENT

- Oil-based ink often flows and spreads more efficiently than conventional solvent-based ink, ultimately reducing the amount of ink needed in the printing process[74].
- Production of soy beans is a major cause of global deforestation[75]– check where soy beans are being grown, if soy-based ink is used.

RECYCLABILITY

- Inks are recyclable under controlled conditions[76 / 77].

HEALTH & SAFETY / LABOUR

- Ensure the ink does not contain solvents (some inks use both water and solvents as vehicles), as the inhalation of harmful volatile organic compounds (toxic fumes) remains a risk[78].

UV/Electronic Beam ink

SCORE BREAKDOWN

DESCRIPTION

There are specially-formulated types of ink that dry through UV and/or electronic beam (EB) radiation[79]. This ink does not contain solvents.

ENVIRONMENT

- UV ink can be energy-intensive, although EB is less so. Costs of both processes are fairly high due to the technological complexity of the ink[80].
- As the ink cannot be solvent based, it does not contain harmful volatile organic compounds that can impact the environment.

RECYCLABILITY

- Inks are recyclable under controlled conditions[81 / 82].

HEALTH & SAFETY / LABOUR

- As above, the ink cannot be solvent based and therefore will not contain VOCs, which can cause damage to the environment and human respiratory systems through air pollution[83].
- Exposure to UV radiation can cause acute, abnormal redness on skin. Continued exposure, even at low doses can cause a severe reaction[84]. It can also cause serious burns to the eyes[85].

ALTERNATIVES

- Solvent-based ink
- Algae ink – ink products grown from algae. These inks are biodegradable[86].

Dye

SCORE BREAKDOWN

DESCRIPTION

Dye is a colouring material used in printing inks, distinguished from a pigment by its vehicle-solubility, which pigments lack. Dye, though more commonly used in the colouring of textiles, is used in inks to impart a set of desired optical properties that are not achievable with pigments used in traditional ink (e.g. transparency, purity, colour strength)[87]. They are often referred to as 'dye-based ink'[88].

ENVIRONMENT

- Dye leaching into the waterstream can cause significant issues. It takes a very small amount of synthetic dye (<1ppm) to impact water sources – they reflect the sunlight entering water, hindering photosynthesis of aquatic plants and causing oxygen deficiency, limiting downstream uses such as recreation, drinking water and irrigation[89].
- Dye can also be carcinogenic, mutagenic and / or toxic to life – impacting aquatic organisms, sometimes to a great degree[90].
- Most dye escapes conventional wastewater treatment processes as a result of their high stability to light, temperature, detergents and chemicals. They can remain in the environment for an extended period because of their ability to resist biodegradation[91].

RECYCLABILITY

- Dye-based inks are particularly difficult to recycle due to their solubility in water[92].

HEALTH & SAFETY / LABOUR

- Long term or overexposure to dye can cause respiratory problems. They can also impact workers' immune systems and cause reactions such as itching, sneezing and asthma[93].
- Exposure to the chemicals in dye can cause irritation to the skin and eyes[94].
- There has been an increase in the incidence of bladder, kidney and liver cancers in dye workers exposed to large quantities of certain dyes – this is more prevalent in the textile industry, but worth noting in the publishing industry as well[95].

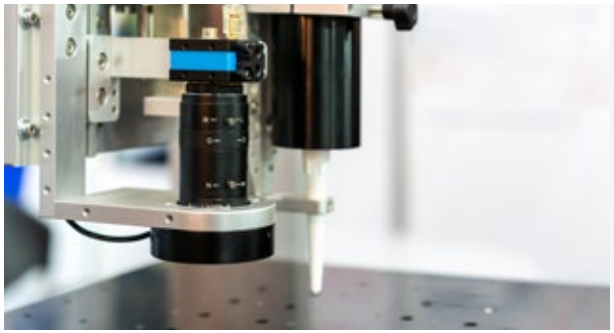
ALTERNATIVES

- Water soluble dye.

Adhesives [hot-melt]

SCORE BREAKDOWN

2-5KG CO_2e per kg of adhesives[96]



DESCRIPTION

An adhesive is a specific substance capable of adhering to a surface, or of facilitating the attachment of two surfaces or substances in varying degrees of permanence or application[97]. Adhesive materials are widely used in binding and finishes for adhering pages together and in adhering pages to covers. There are a wide variety of adhesives available, but most fall under the following: **hot-melt**, **solvent-based**, **water-based** and **animal-based** adhesives. This section covers hot-melt adhesives, which are the common type used in binding as they are the most versatile. They are based on thermoplastic polymers which are melted and applied in a liquid state. Once these have cooled down, they form the bind[98].

ENVIRONMENT

- Materials used for hot-melt include petroleum based polymers, tackifying resins and waxes[99].These raw materials have high carbon footprints as they require energy-intensive processes to source them.
- Hot-melt adhesives do not contain any solvents (therefore do not contain any toxic gases unless they become overheated) and are generally low waste[100].

RECYCLABILITY

- Hot-melt adhesives do not disperse in water and this makes them very difficult to recycle. During the recycling process, they produce 'stickies' which are tacky substances that get caught in machinery and water systems[101]. Some adhesives use raw materials such as base polymers, resins and waxes that are not biodegradable or recyclable.
- They must be disposed of by a licensed disposal facility[102].

HEALTH & SAFETY / LABOUR

- Hot-melt adhesives are used in their molten state, so burns from contact can be severe[103].
- Hot-melt adhesive fumes can become toxic if they are overheated – overheating results in chemical breakdown, causing toxic organic materials to release which may impact workers' respiratory systems[104]. In a controlled environment, it is unlikely that the adhesive will be overheated.

ALTERNATIVES

- **Solvent-based adhesives**
- **Water-based adhesives**
- **Animal-based adhesives**

Adhesives [solvent-based]

SCORE BREAKDOWN

2-5KG CO_2e per kg of adhesives[105]

DESCRIPTION

An adhesive is a specific substance capable of adhering to a surface, or of facilitating the attachment of two surfaces or substances in varying degrees of permanence or application[106]. Adhesive materials are widely used in binding and finishing for adhering pages together and in adhering pages to covers. There are a wide variety of adhesives available. **Solvent-based adhesives** use a solvent as their base ingredient, into which a polymer is dissolved to make it sticky[107]. Solvent-based adhesives are traditional adhesives and dry quicker than other options. However they are becoming more difficult to use as the solvent industry is increasingly regulated due to its toxic content[108].

ENVIRONMENT

- Solvent-based adhesives have very high volatile organic compound (VOC - toxic gas) content. They release VOCs into the atmosphere at all stages of the manufacturing and drying process. VOCs contribute to air pollution and climate change[109].
- Solvent-based adhesives are extremely toxic and if discarded into landfill will contaminate the soil and groundwater. This can lead to the destruction of life and flora, and potentially contaminate drinking water causing major health risks[110 / 111].

RECYCLABILITY

- Solvent-based adhesives are not recyclable[112].
- Non-soluble adhesives should not be discharged to sewers but collected by a licensed contractor and disposed of at a licensed disposal facility[113].

HEALTH & SAFETY / LABOUR

- Solvent-based adhesives are harmful to air quality due to their high VOC content. Breathing in solvent-based adhesives can lead to a number of health concerns including; respiratory inflammation, asthma and lung disease. Solvents can also affect the brain and can be stored in the brain's fatty tissue[114].
- Solvent-based adhesives are highly flammable, so require proper precautions for handling[115].

ALTERNATIVES

- **Water based adhesives**
- **Hot-melt adhesives**
- **Animal-based adhesives**

CONTENTS

Adhesives [water-based]

SCORE BREAKDOWN

1-3KG CO_2e per kg of adhesives[116]

DESCRIPTION

An adhesive is a specific substance capable of adhering to a surface, or of facilitating the attachment of two surfaces or substances in varying degrees of permanence or application[117]. Adhesive materials are widely used in binding and finishes for adhering pages together and in adhering pages to covers. There are a wide variety of adhesives available. **Water based adhesives** are either pre-mixed solutions or formulated as dry powders which are then mixed with water. They can contain both natural polymers, derived from vegetable, protein or animal sources, and soluble synthetic polymers[118]. This section focuses on synthetic water-based adhesives, the most commonly used of all water-based adhesives[119]. There is an additional section on **animal-based adhesives**.

ENVIRONMENT

- Water-based adhesives are easy to remove and do not require the use of a solution with high chemical content[120].

RECYCLABILITY

- Water-based adhesives are soluble in water so do not prevent paper from being re-pulped and reused[121].

HEALTH & SAFETY / LABOUR

- Ventilation is vital even with water-based solvents, to minimise toxin inhalation, although they are significantly lower in volatile organic compounds than their solvent counterparts[122].
- Water-based adhesives can be applied at room temperature, so there is no danger of receiving burns[123].
- Water-based adhesives are easier to use than other types of adhesives as they can be applied in various different ways (including rollers, spray guns and immersion) and do not clog machines as it dries[124].

ALTERNATIVES

- **Hot-melt adhesives**
- **Solvent-based adhesives**
- **Animal-based adhesives**

Adhesives [animal-based]

DESCRIPTION

An adhesive is a specific substance capable of adhering to a surface, or of facilitating the attachment of two surfaces or substances in varying degrees of permanence or application[125]. Adhesive materials are widely used in binding and finishes for adhering pages together and in adhering pages to covers. There are a wide variety of adhesives available. **Animal based adhesives** are derived from gelatin that is extracted from collagen, a naturally occurring substance found in bovine and porcine hides, and combined with an acid, alkali or hot water to make it soluble and useable[126]. Until the introduction of synthetic adhesives, animal adhesive was the preferred gluing agent due to its great versatility and usefulness in various fields of application[127].

ENVIRONMENT

- The chemicals used in animal-based adhesives are not usually environmentally hazardous, however the production produces a large amount of waste-water that must be treated to reduce the solids content[128].
- Using animal-based adhesives would not be vegan-friendly[129].

RECYCLABILITY

- Animal-based adhesives dissolve quickly and are safe and biodegradable[130]. They are also easy to re-pulp, meaning they don't prevent the paper from being reused[131].

HEALTH & SAFETY / LABOUR

- Ventilation is vital even with water-based solvents, to minimise toxin inhalation, although they are significantly lower in volatile organic compounds than their solvent counterparts[132].
- Water-based adhesives can be applied at room temperature, so there is no danger of receiving burns[133].
- Water-based adhesives are easier to use than other types of adhesives as they can be applied in various different ways (including rollers, spray guns and immersion) and do not clog machines as it dries[134].

ALTERNATIVES

- **Hot-melt adhesives**
- **Solvent-based adhesives**
- **Water-based adhesives**

CONTENTS

Hot-foil stamping

SCORE BREAKDOWN

9.1226KG CO_2e per kg of foil[135] (Foil alone)

DESCRIPTION

Foil is adhered to a page using pressure and heat – a heated die (a thin, sharp blade) is pressed onto a sheet of foil with paper underneath. The die is cut in the intended design or pattern, meaning that when it is pressed against the page it leaves the design on the page, and cuts out the rest of the foil. This foil is then rolled up and reused in the process[136]. Hot foil stamping is completed by a complex, automated machine. Hot foil can be applied to rough and embossed paper[137].

ENVIRONMENT

- Multiple runs make it more energy intensive[138].
- Energy is used to heat the metal[139].

RECYCLABILITY

- Alone, foil is recyclable and there is little wastage as the machine rolls up and reuses the spare foil[140]. However it is not recyclable after it is adhered to a page[141].

HEALTH & SAFETY / LABOUR

- This process is normally fully automated, no known health and safety or labour issues.

Cold foiling

SCORE BREAKDOWN

DESCRIPTION

Adhesive that can be cured by UV light is placed on the paper or board in the shape of the design desired. Foil is then placed on top, and pulled away where there is no adhesive, leaving the foil imprint[142]. The paper is then run under UV light to dry it. It can only be used on a flat smooth material, and cannot be combined with embossing[143].

ENVIRONMENT

- UV light can be very energy intensive[144].

RECYCLABILITY

- Alone, foil is recyclable and there is little wastage as the machine rolls up and reuses the spare foil[145]. However it is not recyclable after it is adhered to a page[146].

HEALTH & SAFETY / LABOUR

- This process is normally fully automated, no known health and safety or labour issues.

ALTERNATIVES

- Liquid foil. This is a metallic coating, mixed like an ink, that looks like foil when cured with UV light[147].
- Spectrum silver foil: Contains pigments that change colour in the light – produces holographic designs[148].
- Digital Foil Printing – Not as time consuming or costly as designs are stored and created digitally[149].

Recycled paper

SCORE BREAKDOWN

DESCRIPTION

Recycled paper is new paper made entirely or in part from old paper. The process involves mixing used paper with water and chemicals before being broken down into strands of cellulose, which is a type of organic plant material. This pulp is strained through screens to remove any remaining laminate or adhesive in the mixture. It is then cleaned, de-inked, bleached and mixed with water and can be made into recycled paper[150 / 151].

ENVIRONMENT

- The process of recycling paper involves various chlorinated compounds (e.g. bleach), emissions of oxygen-depleting substances, and air emissions of sulphur and nitrogen oxides[152]. These can all be damaging to the environment in different ways.
- Pulp needs to be mixed with hot water, solvents and detergents to dissolve and disperse adhesives, laminates, inks etc. These chemicals can be resistant to the cleaning process, meaning that there is a risk of them ending up in the waste system through waste water[153].

RECYCLABILITY

- Using recycled paper reduces the number of trees cut down, conserving natural resources. Every tonne of recycled fibre saves an average of 17 trees and related pulping material[154]. Using recycled paper contributes to the circular economy and is a step towards closing the loop.
- The estimates of energy savings with recycling paper vary greatly – most studies indicate that energy savings of 7-57% are possible for paper products, but paperboard is expected to require more energy when manufactured from recycled material[155].
- Despite this, for the lifecycle of the product (including transport etc.) the recycled paper uses much less total energy than the virgin paper system. Virgin paper requires more water and yields wastewater that has significantly higher levels of major water pollutants than recycled paper production[156].

HEALTH & SAFETY / LABOUR

- Contact with the chemicals in recycling plants can cause nose, throat and eye irritation, as well as damage to the lungs if inhaled[157].
- The chemicals used in pulp mills have been linked to an increased risk of cancer – however this is relevant to virgin pulp as well[158].

ALTERNATIVES

- Virgin paper
- **Woodfree paper**
- **Coated paper**
- Agripulp paper: using agricultural and post-consumer waste to make paper, with process effluents going into fertilisers[159].

Woodfree paper

SCORE BREAKDOWN

DESCRIPTION

Woodfree paper is paper made from chemical pulp. Chemical pulping is a method of converting woodchips into paper pulp by heating the woodchips in chemicals – to make woodfree paper, the lignin (the 'wood') is removed[160]. Woodfree paper can be coated (glossy) or uncoated (matte)[161].

ENVIRONMENT

- Chemical pulping can provide the bulk of the energy required to sustain the process , in some cases it can become a net energy producer[162 / 163].
- Chemical pulping causes greater environmental pollution than mechanical pulping and a lower yield[164].

RECYCLABILITY

- Woodfree paper is fully recyclable[165].

HEALTH & SAFETY / LABOUR

- Sodium Hydroxide is often used for chemical pulping. Sodium Hydroxide can be irritating and corrosive, causing severe burns and sometimes permanent damage to any tissue it comes into contact with. Sodium Hydroxide can also burn the eyes, and lead to permanent eye damage[166].
- The chemical processing can cause high dust levels, which may cause eye, nose and throat irritation[167].

ALTERNATIVES

- **Recycled paper**
- Virgin paper
- **Coated paper**

SCORE BREAKDOWN

Coated paper

DESCRIPTION

The last stage of paper making is the coating. To fill in the crevices of the paper, it is covered in either white clay (kaolin), chalk filler, precipitated calcium carbonate or talc. This coating is responsible for 10-30% of the paper thickness[168]. Inks are not absorbed well into coated paper, so they often need additional finishes (e.g. varnish / lamination) to help prevent ink smudging[169]. Coated paper makes the printed material shiny and bright, which is why it is typically used for brochures, glossy photos, booklets, and more. The coating restricts how the paper absorbs ink and is therefore used for more complex designs or images that must be sharp. Uncoated paper, on the other hand, is rougher and more porous, which makes it very absorbent. This tends to be more favourable for novels or books that will be written in[170].

ENVIRONMENT

- The raw materials used for the coating are obtained through pit mining. This process can lead to loss of biodiversity, erosion, increased air pollution from dust particles, groundwater contamination and surface level water pollution if done near water bodies[171].

RECYCLABILITY

- Coatings can make paper more difficult to recycle. Clay in particular clogs recycling machines, and as the coating is not removable, it renders the paper non-recyclable[172].

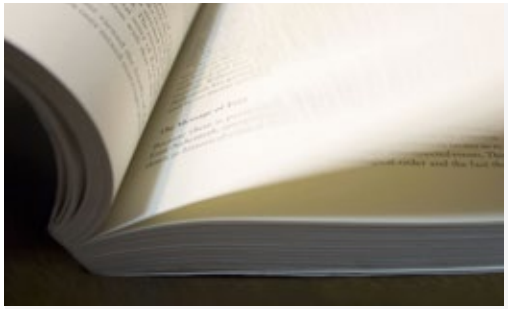
HEALTH & SAFETY / LABOUR

- The raw materials used for coating are obtained through pit mining. As well as the environmental issues this process brings, pit mining can cause air pollution. Increased air pollution can cause respiratory issues[173].
- Raw kaolin (used as one of the coating materials) is typically extracted in open pit mines[174].
- Kaolin mines can be found all over the world, with the 5 largest exporters of kaolin being the US, Belgium, UK, Brazil and Ukraine[175].
- Mining standards vary between country, it is therefore important to find out where the raw kaolin for your coated paper originates from and to understand the mining issues in the specific country of origin.
- Kaolin can be harmful when inhaled, as it causes lung inflammation which can develop into the formation of tissue deposits over time. Workers involved in the production and distribution of kaolin can be susceptible to this[176].

ALTERNATIVES

- **Recycled paper**
- Virgin paper
- **Woodfree paper**

Cut-flush binding



SCORE BREAKDOWN

DESCRIPTION

Cut-flush binding is a cover cut to the same size as the inside body pages, leaving no overhang[177].

ENVIRONMENT

- No known issues.

RECYCLABILITY

- N/A as depends on the book.

HEALTH & SAFETY / LABOUR

- A sharp blade is used to cut the paper, which could pose H&S risks. However, this process is almost always automated, which reduces the risk[178].

Sewn binding

SCORE BREAKDOWN

DESCRIPTION

Sewn binding is the process of sewing the papers along the spine, to bind the book together. Adhesives are sometimes used to reinforce the sewing and maintain a convex shape to the spine of the book. This is an automated process[179].

ENVIRONMENT

- No known issues.

RECYCLABILITY

- N/A as depends on the book and adhesive used, if any.

HEALTH & SAFETY / LABOUR

- No known issues – relies on safe use of binding machinery.

Quarter binding

SCORE BREAKDOWN

DESCRIPTION

Quarter binding is where the spine is covered in a different material to the front and back cover – traditionally leather or cloth[180 / 181].

ENVIRONMENT

- No known issues.

RECYCLABILITY

- N/A as depends on the book and adhesive used.

HEALTH & SAFETY / LABOUR

- No known issues – relies on safe use of binding machinery.

ALTERNATIVES

There are many types of binding, with cut-flush, sewn and quarter binding being the most common within our publishers. Some alternatives are:

- Adhesive binding
- Half binding and full binding

Shrinkwrap

SCORE BREAKDOWN

DESCRIPTION

Shrinkwrap is a thin, normally clear, plastic sheet made from polyethylene (PE) or polyvinyl chloride (PVC). Shrinkwrap is normally used to protect books during transit – to seal the pallet together or to individually wrap each book[182]. It keeps them clean and can prevent tampering to individual books during transit or on the shelves in store[183].

ENVIRONMENT

- If shrinkwrap is incinerated, it can release highly toxic chemical compounds called dioxins. On top of the serious H&S issues these chemicals can cause, dioxins are known as persistent environmental pollutants (POPs) and can remain in the environment for many years[184].
- If shrinkwrap makes its way into the ocean, the plastic binds with bacteria and metals and thus is easily mistaken for food by sealife, which can be harmful. It can also bring plastic into the food chain[185].

RECYCLABILITY

- Shrinkwrap is made of very thin, sticky plastic and can be hard to recycle. It requires specialist recycling facilities in order to do so[186].

HEALTH & SAFETY / LABOUR

- If shrinkwrap is incinerated it can release highly toxic chemical compounds called dioxins. Dioxin can cause serious issues to development of children and babies, and impact the immune system. They can also disrupt hormones and lead to cancer[187].
- During the manufacturing process, shrinkwrap can have phthalates or bisphenol A (BPAs) added to it, which are endocrine disruptors. Endocrine disruptors are chemicals that impact the body's normal hormone levels, and can cause birth defects and cancer, and are closely linked with developmental issues[188]. Workers can be exposed to these chemicals by breathing in fumes during the manufacturing process.

ALTERNATIVES

Shrinkwrap is endemic across manufacturing supply chains and is notoriously difficult to replace. Some options are:

- Not individually wrapping books, thereby reducing the amount of plastic used. This may mean you need to use **laminate** or **varnish** to protect the books instead.
- Using paper in between books instead, although this can sometimes result in higher emissions[189]. It is important to assess alternatives in your own supply chains.

Belly bands / J bands

SCORE BREAKDOWN

DESCRIPTION

Belly and J bands are a sheath of material (usually paper) which is wrapped around a book. They are used for a number of reasons, usually to provide extra space for information about the book[190].

ENVIRONMENT

- Belly and J bands are normally made out of thin material, intended to be disposed of after the content is read.

RECYCLABILITY

- Recyclability depends on the material the belly band is made out of.

HEALTH & SAFETY / LABOUR

- No known health and safety or labour risks, although belly bands are usually very thin and flimsy so can be difficult to work with and ship[191].

Head and tail bands

SCORE BREAKDOWN

DESCRIPTION

Head and tail bands are small sections of coloured fabric, used on the top and bottom of the spine of hardcover books. Head and tail bands can be useful if you want a built in fabric bookmark[192].

ENVIRONMENT

- No known risks.

RECYCLABILITY

- Recyclability depends on the material the belly band is made out of.

HEALTH & SAFETY / LABOUR

- No known risks.

ALTERNATIVES

No known alternatives.

SCORE BREAKDOWN

Flocking

DESCRIPTION

Flocking describes the process where lots of small fibres are applied to an adhesive-coated surface – the texture produced can either be soft and velvety, or hard and bristly[193]. The fibres applied are electrically negatively charged, and the paper/surface is earthed, so that the fibres are attracted vertically to the paper, which has previously been covered in adhesive[194]. The fibres are traditionally made from nylon, viscose or polyester. Traditionally, it was used on children's books, although the health and safety risks associated with it mean that the process is becoming less common[195].

ENVIRONMENT

- Environmental issues with flocking can depend on the type of adhesive used. For further information on adhesives, view them here: **solvent-based adhesives**, **hot-melt adhesives**, **water-based adhesives**, **animal-based adhesives**.

RECYCLABILITY

- Flocked paper cannot be recycled[196].

HEALTH & SAFETY / LABOUR

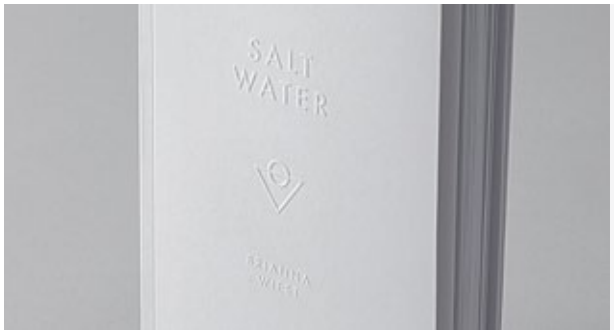
- The process exposes workers to flock fibres that are loose in the air. When these fibres are inhaled, they get lodged into the lungs causing the workers to develop flock workers lung[197]. Flock workers lung can be demonstrated through persistent respiratory symptoms that cause interstitial lung disease and pneumonia[198].
- The process requires a specific room on site with a ventilation system to protect workers, separate to the usual printing room. This is also required to ensure the right atmospheric conditions (temperature and humidity controlled)[199]. Some printers do not offer flocking at all, due to the additional machinery and room required, as well as worker health risks.

ALTERNATIVES

No known alternatives.

SCORE BREAKDOWN

Embossing/debossing



DESCRIPTION

Embossing and debossing is the process of creating a design that is either protruded from a sheet of paper, or sunk into the paper itself[200]. Two metal dies are used to create the design – one with a raised design, and one with a recessed design[201]. Paper is placed between the two dies and heat and pressure are applied to squeeze the two dies together and impart the design (whether it is raised or sunken). The paper fibres permanently reshape to take on the intended design.

ENVIRONMENT

- Requires the creation of two unique metal dies which cannot be used again. It is energy-intensive to get the dies reprocessed by melting them down again[202].

RECYCLABILITY

- If no additional materials are used, embossing or debossing does not make a difference to the recyclability of the paper.

HEALTH & SAFETY / LABOUR

- No known health and safety or labour issues as the process is automated. Correct use of machinery is paramount.

ALTERNATIVES

No known alternatives.

SCORE BREAKDOWN

Glitter

DESCRIPTION

Glitter are tiny shiny pieces of plastic that come in various colours. They are usually used for decoration, particularly on children's' books.

ENVIRONMENT

- Glitter is a form of microplastic. Microplastics are small plastic pieces less than five millimetres long which can be harmful to the planet, particularly oceans and aquatic life[203]. They can be ingested by aquatic life with fatal consequences, and they can also find their way into the food chain when people consume seafood.
- There have been global campaigns to ban glitter[204].
- Glitter is already banned in cosmetics and personal care products, so this ban could potentially be extended[205].

RECYCLABILITY

- Glitter is not recyclable, as the tiny particles clog recycling machines[206].

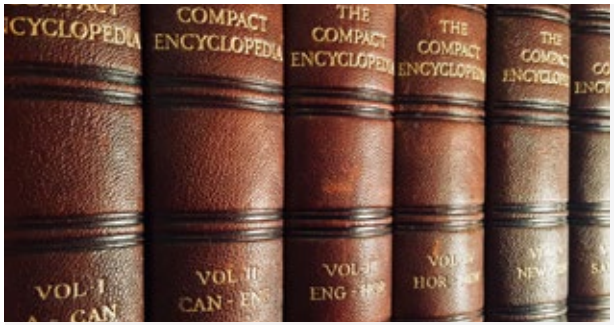
HEALTH & SAFETY / LABOUR

- If glitter is inhaled, it can get caught in the bottom of the lungs and the body is not able to remove it. They can cause infections, lung disease and limited lung capacity[207].
- Glitter is extremely abrasive, so if it gets into eyes it can cause corneal ulcers (which, in turn, can cause blindness). Correct personal protective equipment must be worn[208].
- Glitter can be attached to books with toxic adhesive that is dangerous for workers to handle[209]. You can find further information on adhesives here: **hot-melt adhesives**, **solvent-based adhesives**, **water-based adhesives**, **animal-based adhesives**.

ALTERNATIVES

- Synthetic mica, made from fluorphlogopite - mimics natural Mica but is created in a lab. Doesn't contain microplastics as it's made of natural minerals[210].
- Biodegradable glitter made from cellulose (eucalyptus trees) that breaks down in the natural environment[211]
- Biodegradable glitter – plastic free and degrades in water[212].
- Mica – a natural occurring mineral (however there are some serious child labour issues associated with mica, so this would be an option that should be fully investigated before proceeding – perhaps in association with the Responsible Mica Sourcing Initiative)[213].

Gilding



SCORE BREAKDOWN

DESCRIPTION

Gilding describes the process used to add thin gold detailing to any surface of paper. It is normally used to make books appear more elegant and expensive[214 / 215].

ENVIRONMENT

- Gilding tends to use adhesives to attach the gold substance – see the following for further information on adhesives: **hot-melt**, **solvent-based**, **water-based** and **animal-based adhesives**[216].

RECYCLABILITY

- Recyclability depends on the substance applied to the book.

HEALTH & SAFETY / LABOUR

- Gilding is a labour intensive process, often done by hand[217].

Spray edges

SCORE BREAKDOWN

DESCRIPTION

Spray edges describe the process of ink or foil being applied to the three exposed edges of paper in a book[218].

ENVIRONMENT

- Environmental impacts depend on the type of material used to create the edges. **Click here for further information about foil**.

RECYCLABILITY

- Recyclability depends on the substance applied to the book.

HEALTH & SAFETY / LABOUR

- If various inks are being used, they are often hand mixed to get the right colours. This means workers risk exposure to ink. Find more about inks here: **solvent-based ink**, **water-based ink**, **oil-based ink**, and **UV / electronic beam ink**[219].

ALTERNATIVES

No known alternatives.

Design Guide emissions factors

The Design Guide was first created by the Book Chain Project back in 2020, as a resource for design teams to draw from when creating the specifications for a new book. As the Design for Sustainability agenda continues to grow, and the interest in understanding and reducing the emissions associated with creating books remains at the forefront, we decided to build on the existing Design Guide with some details on emissions factors for a select number of materials and processes.

We asked the Chemicals & Materials publishers to vote for their preferred materials and processes and were left with five to do a deep-emissions-dive on: **ink**, **laminate**, **adhesives**, **varnish** and **hot-foil stamping**. In 2022, we conducted desk-based research, investigating large manufacturers and industry bodies, and reached out to suppliers on the Book Chain Project database that use the materials chosen with further questions. As a result, we have come up with emissions factor data that can be used for all five materials and processes, although not all of them are equally as substantiated.

... we decided to build on the existing Design Guide with some details on emissions factors for a select number of materials and processes.

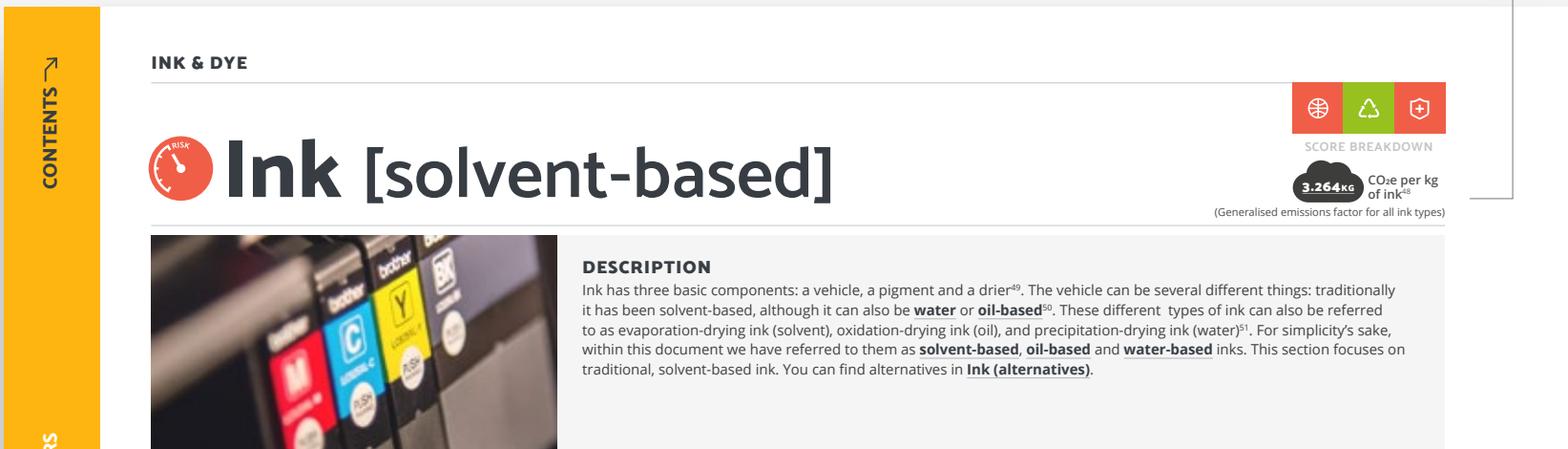
Both ink and adhesives have a relatively substantial amount of information published on emissions factor data, largely down to the work of various industry bodies that are focusing on this. Laminate had little information, and varnish and hot-foil stamping had none that was publicly available.

Based on this, we have used some assumptions. Where emissions factor data was available, we have used it: namely for ink, adhesives and laminate. We were only able to find a generalised emissions factor for ink and varnish, but we did manage to get hold of individual emissions factors for solvent, hot-melt and water-based adhesives. We were not able to find an emissions factor for animal-based adhesives. Where emissions factor data was not available, we did some research on the materials or processes and built some figures based on proxies. We understand from various sources that traditional varnish (note: not UV varnish or aqueous coatings) is essentially the vehicle of ink, just without the pigment[220 / 221 / 222 / 223]. We have been informed through interviews that the pigment makes up a large proportion of the footprint of ink, therefore it is safe to assume that the emissions factor for ink can be used as a substitute for varnish, until more emissions data are released on the material in the future. We understand this may be overestimating, but it's better to overestimate and revise that estimate when more data is available, than the other way round.

Finally, hot-foil stamping was a little more difficult. We could not find any publicly available information on emissions factors, or even anecdotal information from interviews. Because of this, we have used the emissions factor for foil alone, not including the stamping process.

All emissions factor data is based on cradle-to-gate, covering the material from production of raw material to the final product. It does not include printing itself.

Emissions factor data



ENDNOTES

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