PACKAGING UNWRAPPED

EXPLORING THE ENVIRONMENTAL IMPACTS OF GLOBAL MATERIAL FLOWS RELATING TO THE UK'S PACKAGING CONSUMPTION

WWF FOR YOUR WORLD

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Tesco Enfield sorting facility

1.0 SUMMARY

The packaging we use in the UK is made from a range of materials. Each material has its own unique supply chain, with environmental and social impacts at every stage, from the processing of the raw materials to disposing of waste. These impacts are felt not just in the UK, but all over the world.

This study aims to unravel these complex supply chains and understand the impacts that take place during each stage. Identifying where these happen gives us a fuller picture of the global footprint of UK consumption, and supports the ambition of the Tesco-WWF partnership to "halve the environmental impact of the UK shopping basket."

The environmental and social impacts of the UK's packaging consumption extend far beyond our shores. The key to minimising our footprint is to understand what these impacts are and where they are occurring. This study investigates the supply chains of five key materials – aluminium, steel, glass, paper and board, and plastic – to identify where the environmental hotspots lie, both in the value chain and geographically.

Adopting a circular economy is an essential part of reducing the UK's packaging materials footprint. But circularity primarily focuses on the end-of-life stage, giving less consideration to mitigating life-cycle impacts through the materials supply chain. This study aims to give an overview of the impact of UK consumption of each material on ecosystems and human health, zooming in on the countries where these impacts are most significant. It also aims to highlight areas where there is a lack of transparency in relation to the movement of virgin, recycled and waste packaging.

The study focuses on consumer packaging for products sold by retailers such as supermarkets and by the hospitality sector. Commercial and industrial packaging, such as pallets and drums, is beyond the scope of this research. The findings in this report are also relevant beyond the packaging sector, however, as key resources are often extracted from a limited number of resource-rich countries, meaning other industries may share similar value chains.

Importantly, the study does not aim to make comparisons between materials. Materials are not inherently good or bad: each has its own particular uses, strengths and weaknesses. While reducing the amount we use should remain a priority, the UK will continue to need packaging. By understanding the issues related to each material, we can take targeted action to minimise the negative impacts and strengthen the sustainability of the materials we use.

Materials are not inherently good or bad: each has its own particular uses, strengths and weaknesses. By understanding the issues related to each material, we can take targeted action to minimise negative impacts and strengthen sustainability.

Table 1 summarises the environmental hotspots identified in the value chain for each material, as well as gaps in knowledge or data that point to uncertainty around environmental outcomes and limit possible remedial action.

It is not intended as a comparison between materials but shows that each one has its own challenges and identifies elements of the life cycle that require attention.

Key

- Green: Good data and/or low environmental impacts
- Yellow: Missing or poor environmental data particularly in the way impacts vary by locations. A focus area after significant hotspots have been addressed.
- Pink: A significant environmental hotspot in the process and/or a large gap in knowledge/transparency that is preventing action or hiding impacts.

Table 1-1: Environmental and Supply Chain Transparency Hotspots

LIFE CYCLE	ALUMINIUM	STEEL	GLASS	PAPER	PLASTIC
DESIGN	Can design is extremely well optimised, but aluminium foils are often used in products which are unlikely to be recovered and recycled. Polymers, often used as coatings, are not recovered during recycling.	Can design is well optimised and generally used in appropriate applications.	More consideration could be given to optimising material use through light weighting.	Paper is increasingly being used inappropriately as a substitute for plastics and polymers are often still required as a 'hidden' barrier layer.	Plastic is often specified in applications where it cannot currently be recovered and recycled at end-of-life.
RAW MATERIAL EXTRACTION	No location-specific data is available on mining impacts; local ecosystem impacts are likely to vary depending on location. Concerns over social impact of mining, particularly in Guinea.	No location-specific data is available on mining impacts; local ecosystem impacts are likely to vary depending on location. Concerns over social impact of mining, particularly in South America.	No location-specific data is available on mining impacts. Currently, it appears mining has relatively low impacts.	Typically from well-regulated European forestry. Compared with other sourcing regions, local ecosystem impacts are likely to be disproportionately high for the small volume of wood imported from South America.	No location-specific data is available on petrochemical extraction and processing impacts, making it difficult to ascertain the specific impacts associated with plastic produced in different parts of the world. Life-cycle inventory is usually aggregated, lacks transparency and/or is not updated regularly which means decisions related to environmental impacts can be difficult to justify. The UK's move towards US shale gas for plastics production also raises uncertainty, particularly due to methane emissions associated with extraction.
RAW MATERIAL PROCESSING AND MANUFACTURE	The geographic differences in smelting energy sources and the resulting impacts are well understood. Smelting location is the most significant factor determining the overall impact of aluminium production.	Geographic differences are unclear, but unlikely to be very influential. With the global reliance on coking coal and use of alternative energy sources such as hydrogen requiring significant investment, the pathway to net zero remains unclear.	Geographic differences in impact for glass manufacture are not well understood. The heating and melting of raw materials to produce glass is the production stage with the largest impact.	Pulping is the stage with the largest environmental impact. Location specific data is not readily available.	
WASTE COLLECTION	Collection and sorting well established for cans, but not for foils.	Collection and sorting well established.	Collection and sorting well established although losses are high.	Collection and sorting well established.	Collection and sorting well established for bottles but not for other consumer plastics.
WASTE PROCESSING	Remelting of aluminium is common and has been integrated into the aluminium supply chain. Aluminium cans are generally kept separate from other aluminium streams to maintain quality.	Remelting of steel is common and has been integrated into the steel production process.	Secondary glass is fully integrated into the glass manufacturing process. A large proportion of collected material is still used as an aggregate substitute, reducing secondary material value and increasing embedded energy required to produce virgin glass.	Paper/board recycling is an integral part of the primary material process. The UK cannot recycle all of its paper due to the disproportionate amount of imported paper relative to domestic production which means capacity is limited.	Recycling typically takes place for PET bottles but is very limited for other packaging types and is not efficiently integrated into primary production. Data on plastics recycling processes is limited.
WASTE EXPORTS	A high proportion of waste cans are used for can making in the UK before export so are no longer considered waste, but the UK's lack of rolling mills results in potentially unnecessary movement to and from the EU.	UK exports a large proportion of its steel scrap. The high value and recyclability mean it is very likely to be recycled regardless of end destination.	Exports are relatively small and remain mostly in Europe.	UK exports a large amount of material to countries in Asia where there is no clear understanding of its end use. There is particular uncertainty with regards to Indonesia – specifically the relationship between recycling and the Indonesian paper industry's links to deforestation.	UK exports a large amount of material to countries in Asia with no clear understanding of its end fate.

1.1 ACTIONS TO REDUCE PACKAGING SUPPLY CHAIN FOOTPRINT

Following the waste hierarchy remains key to reducing the UK's packaging footprint. This means prioritising a reduction in packaging and identifying opportunities for reuse ahead of recycling.

But it's also vital to reduce the impact of the packaging materials we do use. The following four overarching principles aim to guide actions to address the areas for improvement identified in this research.

1 Define what sustainability means for each material and identify the most appropriate material for an application.

There is likely to be significant potential to improve the environmental performance of packaging materials by making changes to supply chain and sourcing approaches. Determining the most appropriate material for an application requires direct collaboration with the supply chain, a focus on fitness for purpose, and prioritising the best environmental and social options above marketing priorities.

2 Use sustainably sourced and recycled materials throughout packaging supply chains and promote accreditation for all materials.

Sustainable sourcing and accreditations are voluntary rather than standard practice through all material supply chains. Alongside transparency, improved independent accreditation will provide a framework for change. But this requires deeper supply chain knowledge to enable proactive choices. Consistent, up-to-date and country-specific data would support improvements within supply chains and inform decision-making.

3 Increase understanding and transparency of the movement of virgin, recycled and waste packaging materials at different parts of the value chain.

There are no straightforward ways of mapping the value chain for packaging and its impacts outside of the UK, particularly for the significant volumes of imported packaged products where the packaging origin is unknown. A key knowledge gap for all materials is the origin of filled packaging that is imported from outside Europe – this represents around 10-25% of demand and possibly an even greater share of the environmental impacts. A significant proportion (20-40%) of filled packaging is thought to come from Europe, though this is an assumption based on food imports and may not hold true for non-foods. Greater transparency and traceability in supply chains for filled imports, particularly from outside Europe, should be a priority.

4 Encourage more circular loops within the UK and develop capacity to process waste material to improve its quality before export.

There is considerable uncertainty around the fate of low-value waste materials, particularly some types of paper and plastic, and the UK generally lacks the capacity to fully deal with these within its borders. The UK can reduce its global packaging consumption footprint by developing more domestic recycling capacity where appropriate; for materials that may not be viable to recycle within the UK, it should process waste into higher-value products before export e.g. cleaned and sorted by specific grade or polymer type where known end markets exist.

This can also be accelerated by urgently introducing consistent recycling collections to reduce consumer confusion and a UK-wide, harmonised deposit return scheme for all beverage containers.

KEY ACTIONS FOR GOVERNMENT AND BUSINESS

1 Define what sustainability means for each material and identify the most appropriate material for an application.

BUSINESS ACTION

Switch from minimum to maximum weight specifications for glass packaging based on industry best practice, with no distinction between premium and lower tier products.

RESULT

Glass packaging design is driven by minimising environmental impacts rather than marketing.

BUSINESS ACTION

Phase out aluminium in applications where it is unlikely to be recovered and recycled through typical household or commercial waste streams.

GOVERNMENT ACTION

Increase requirements for greater due diligence in relation to packaging materials sourcing as part of tackling the UK's global footprint within the Environment Bill.

GOVERNMENT ACTION

Include aluminium foils in the core set of materials as part of an overall move towards UK-wide consistent and more harmonised recycling collections.

This includes working with waste operators to determine the best solution to enable the correct identification of foils in waste sorting.

RESULT

Reduction in aluminium that is not recovered for recycling and consequently a reduced need for virgin production.

BUSINESS ACTION

Investigate how to specify or design plastic packaging that can be more readily recyclable and develop more partnerships with waste industry actors.

GOVERNMENT ACTION

Expand Producer Responsibility obligations to include fee modulation based on recyclability performance criteria linked to what is actually capable of being recycled.

This can can be backed up by including minimum specifications for market entry that remove the worst offenders..

RESULT

Appropriate use of plastic where its benefits outweigh the challenges associated with its use and end-of-life recovery and management.

2 Increase the use of sustainably sourced and recycled materials throughout packaging supply chains and promote accreditation for all materials.

GOVERNMENT ACTION

Set appropriate packaging-related taxes or recycled content targets to provide the economic incentive to develop the UK plastics recycling industry.

BUSINESS ACTION

Work with suppliers to determine recycled content targets for all packaging types and where possible specify domestically sourced recycled material.

RESULT

The highest levels of recycled material are typically incorporated into packaging.

BUSINESS ACTION

Require packaging suppliers (and all other upstream actors) to be certified to the relevant independent material sustainability accreditation scheme.

Work closely with schemes and independent stakeholders such as NGOs to increase environmental standards.

BUSINESS ACTION

Work towards developing sustainable sourcing and production guidelines and independent accreditation schemes for glass and plastic packaging supply chains.

RESULT

Sustainable sourcing is a requirement for all materials.

BUSINESS ACTION

Ensure all packaging material supply chains provide and maintain life-cycle inventory data, disaggregated by process and geographic region.

RESULT

Life-cycle data is available for businesses to make informed decisions around material and product sourcing for each material type.

3 Increase understanding and transparency of the movement of virgin, recycled and waste packaging materials at different parts of the value chain.

GOVERNMENT ACTION

Revise the existing Producer Responsibility Obligations (Packaging Waste) Regulations to require that more detailed data is collected and published for packaging materials placed on the UK market, including more detailed information on composites/multi-material packaging formats and the country of origin for all processes within the supply chain.

Develop and publish material consumption footprint accounts (to include those impacts taking place offshore) across all industry sectors and consider policies to reduce those impacts.

In line with commitments in the government's 25 Year Environment Plan, set a packaging-related target in the Environment Bill to reduce the UK's global consumption and production footprint.

RESULT

Better activity data is available to monitor the UK's global packaging materials footprint, particularly for imported filled packaging. This can inform consumption reduction target policies.

BUSINESS ACTION

Develop a database of packaging materials to include:

- Material(s) by mass (including all materials in multi-material/composite packaging);
- Designation of packaging (e.g. single material, multi material or composite); and,
- The countries where raw materials are sourced and where components are produced (not where the contained product was imported from).

This information should be available at individual product level.

RESULT

Businesses have improved transparency throughout their supply chains and have more data to inform decision-making.

Suppliers are driven towards greater transparency, resulting in increased sustainable material sourcing practices.

4 Encourage more circular loops within the UK, and where exports are required, develop capacity to process waste material to a higher quality level.

GOVERNMENT ACTION

Develop a strategy for the future of UK steel and its transition toward more sustainable practices.

Support the development of additional steel recycling capacity within the UK that operates on clean energy.

Support the decarbonisation of primary steel production by investing in technology developments needed to remove coking coal from the process – e.g. hydrogen replacement as part of a coherent strategy on how hydrogen is produced and deployed for various purposes in the UK (including as a natural gas replacement for heating homes).

RESULT

A UK steel sector that relies less on primary steel production and imports to fulfil demand.

GOVERNMENT ACTION

Follow through with the government's manifesto commitment to prohibit export of plastic waste to non-OECD countries and export higher quality plastic waste only to OECD countries that have the infrastructure, technology and capacity to recycle imported waste materials.

Ban all exports of mixed plastic waste i.e. unsorted mixed polymers and/or product types.

GOVERNMENT ACTION

Require that exports of all materials for recycling are recycled at their end destination as part of Extended Producer Responsibility obligations, especially plastic and paper which suffer from a lack of verified recycling at present. This should be credibly verified, e.g. through independent third-party auditing, not self-reporting.

RESULT

Paper and plastic waste exported for recycling is recycled into high-grade products and not leaked into the environment nor sent to landfill or incineration.

2.0 METHODOLOGY

The UK imports **9.7** million tonnes of filled packaging – 44% of all packaging used. The origin of this packaging unknown

The analysis for each material is split into two sections: material flows and environmental impacts.

The former addresses the flow of material from extraction through to the manufacture of the final product using trade data and other public sources to determine which activities take place in which countries. The latter takes the available data on the impacts of different processes, such as raw material extraction, and maps this to the trade flows to determine where in the world these impacts are taking place.

The level of detail and accuracy varies between materials. One of the key variables is the amount of raw material processing and production that takes place within the UK compared with imports. Similarly, domestic recycling compared with export for recycling varies between materials. This variation is also linked to the level of domestic production (the ability to reprocess recycled material) and how integrated recycling is to the virgin material production process.

Where it has been possible to apply regional disaggregation, the focus is on the processes that have the biggest environmental and social impacts. As the focus is on the most significant impact contributors, for the purpose of this analysis, some raw material acquisition and processing impacts that take place in other countries are assigned to the primary country (e.g. some petrochemical fuel use during smelting).

Where data is available, environmental impacts are assigned to production processes. As the focus is on the impacts of sourcing virgin material, impacts from recycling processes have not been considered. However, the reduction in demand for virgin material is taken into account. The impacts are shown using two overarching measures: damage to human health and damage to ecosystems. For ease of communicating this complex topic, these overarching measures act as a proxy for a large number of other environmental and social impacts. For example, greenhouse gas emissions (GHGs) into the atmosphere result in climate impacts that affect both human health (e.g. through disease and malnutrition) and ecosystems. For human health, the endpoint unit is DALY – disability adjusted life years – in the population exposed, which is a measure of the life years lost to ill-health, disability or early death. For ecosystem quality, the endpoint unit is PDF – potentially disappeared fraction of species — at the global scale as a measure of species that may be lost.

The aggregation of environmental impacts comes with a significant level of scientific uncertainty, so is best used as signposting for further specific research rather than as a definitive exploration of the exact environmental impact of an activity.

While a consistent approach has been applied to all materials, the differences in data availability and supply chain transparency may cause inconsistencies. Direct comparisons between materials are neither the focus nor advisable based on these results. Further methodological details can be found in the appendices at the end of this report.

2.1 DATA GAPS

Data from the UK's National Packaging Waste Database (NPWD) has been used throughout to determine how much packaging is placed on the UK market. This data also includes the volume of packaging material reported as imported and exported as part of a product, i.e. imported filled product.

Filled imports represent a significant proportion of the overall UK packaging demand — from 30% for plastic and aluminium, to 50% for paper and glass and up to 70% for steel.

However, while the NPWD indicates the mass of packaging imported, it does not detail the packaging's country of origin, so it is impossible to use existing trade data to analyse these supply chains. This is problematic as filled packaging enters the UK categorised only by the product it contains, e.g. food and drink.

There is no way to know the mass or type of packaging that is used from analysing publicly available trade data as the packaging is a hidden component.

In the absence of this specific data, the assumption adopted is that the packaging supply chain is likely to reflect the supply chain of the product's originating country. In 2018, 65% of the UK's imported food products came from Europe (including non-EU countries).[1] With the vast majority of aluminium packaging related to food and drink, we assume that 65% of the imported filled packaging has a similar European-centric supply chain and trade flow. However, as the exact origin of this significant market contributor remains unknown, this presents a significant knowledge gap. Throughout the report the 'unknown' trade flows and environmental impacts relate primarily to this gap.

3.0 ALUMINIUM

The aluminium packaging supply chain has five broad stages:

1. bauxite mining
2. refining into alumina (aluminium oxide)
3. smelting to create the aluminium ingots
4. sheet rolling
5. can forming

Aluminium cans are formed from rolled sheets that can be less than 0.1mm thick, similar to the width of a human hair. This thinness is achievable since the internal pressure of a carbonated drink provides much of the strength before the can is opened. The inside of the can is coated with an epoxy resin to provide protection from the acids in the beverages; the epoxy resin, which makes up around 2% of the overall material mass of the can, is unrecoverable during the recycling process.

In 2018, total aluminium packaging demand was estimated at 194kt, with 120kt of cans placed on the UK market, equivalent to 7.5 billion cans.[2] The remaining aluminium demand primarily comprised aerosols, foil containers and closures. Filled imports represented around one-third (32%) of demand. To reflect food supply chains, we assumed that 65% of these filled imports come from Europe with the remainder classed as 'unknown'.

Aluminium is also contained in composite/multi-layer packaging where it is not the predominant material but is used for its barrier properties. Because organisations in the UK are not required to report all material use but only the dominant material for each pack, there is no firm data on how much aluminium is used across these types of applications. However, liquid beverage cartons, are estimated to contain around 4%[3] aluminium and with around 56kt of cartons placed on the UK market in 2018, 2.2kt of aluminium is not being accounted for (~1.5% of the total UK packaging aluminium). The use of aluminium in multi-layer flexible packaging formats e.g. crisp packets, is less clear as there are no current estimates for this type of packaging. WRAP estimated in 2008 that 139kt of multi-layer flexible packaging was placed on the UK market with a 9.7% aluminium content—13.5kt of aluminium.[4] At the time, the market was expanding considerably for these packaging types so this is likely to be considerably more today.

Of the 194kt of aluminium packaging placed on the market, 75kt of cans were reported recycled and 25kt of aluminium was recovered from incinerator bottom ash (IBA) in 2018. This results in a 51% recycling rate for aluminium packaging for that year. Based on the same data and the estimated UK market for drinks cans, the can-to-can recycling rate is higher at 62%, which suggests 4.7 billion cans were recycled while 2.8 billion were not. As part of this process, the epoxy coating is lost, which amounts to 1,500 tonnes for the recycled cans.

ALUMINIUM PACKAGING MATERIAL FLOWS INTO THE UK

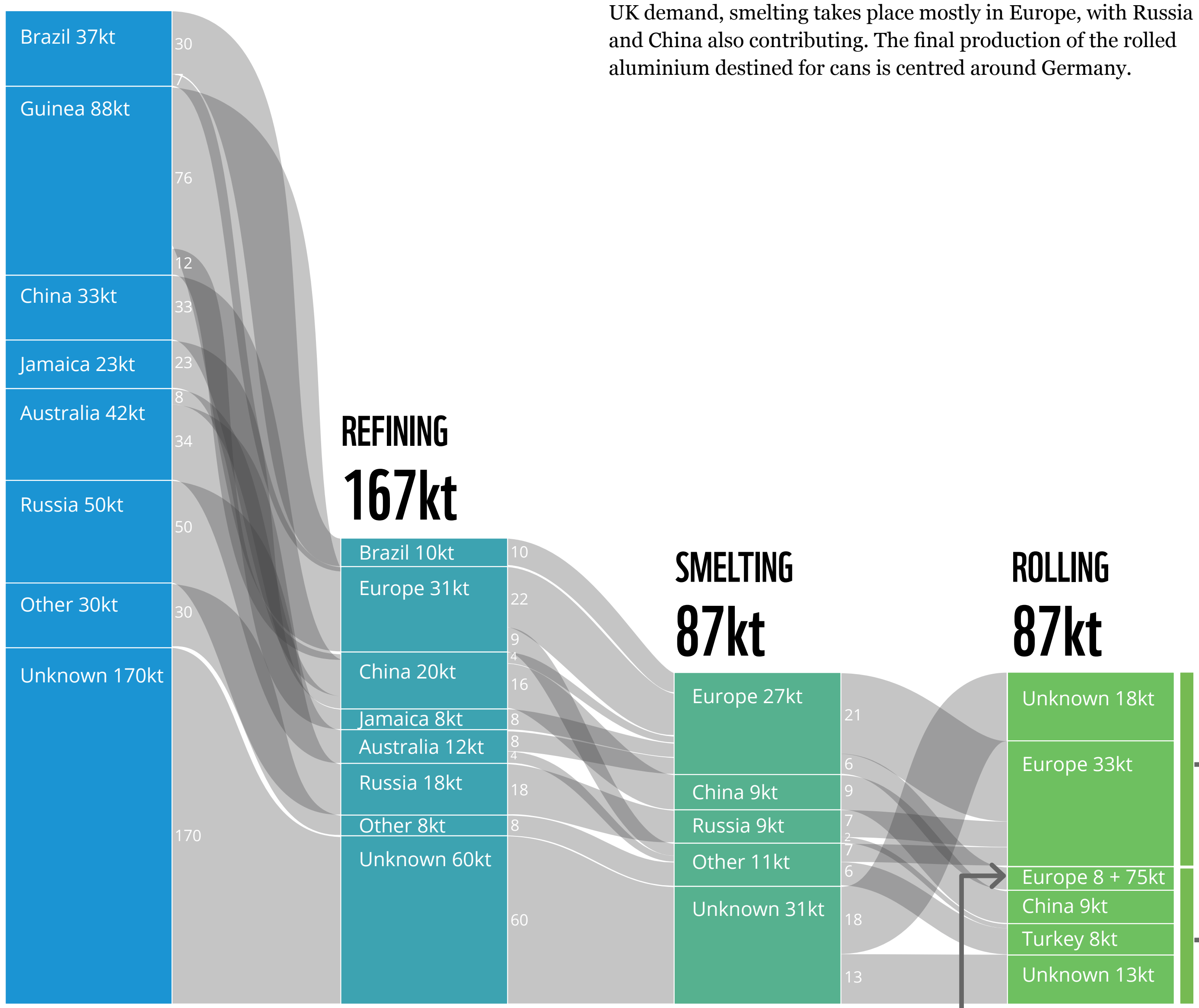
Each of the aluminium processing stages can be performed in a different country, with mining and refining often (but not always) taking place in adjacent locations. Refining close to extraction has the benefit of eliminating transport of large amounts of heavy, unrefined ore across the globe. Refined ore is worth around ten times more than raw ore, which is why most significant ore producers will also refine before exporting. Guinea supplies the highest proportion of bauxite ore, followed by Russia, Australia and Brazil, but is the only large ore producer that does not have any refining capacity. Other countries have attempted to encourage in-country refining by banning bauxite exports, although in the case of Indonesia this came close to destroying the industry as demand went elsewhere.

Smelting takes place all over the world, but mostly in developed countries that have access to the vast amount of energy required to produce the aluminium ingots. Because of this, the plants are often co-located with their own power plant, which in Europe, North America and South America are mostly hydroelectric. For UK demand, smelting takes place mostly in Europe, with Russia and China also contributing. The final production of the rolled aluminium destined for cans is centred around Germany.

Aluminium can recycling is largely a closed-loop system where cans are kept separate and either exported or remelted and then exported as ingots to be used in new cans. The UK has significant aluminium can recycling capacity and even imports used cans from other European countries to be turned into ingots. However, as the UK does not have the capability to roll ingots into sheets, these are often exported to Germany to be rolled and then re-imported to be converted to cans. With a can-to-can recycling rate of 62%, the 2018 UK demand for virgin aluminium for the packaging industry sits at around 33,000 tonnes.

Aluminium can also be recovered from the ash after waste incineration, but this activity is not tracked, and no official data exists around its end destination and use. However, there are no reports of it being used in can stock (which is a highly controlled and specific material), and 95% is exported out of the UK. It is also unclear what happens to many foils as recycling is not reported separately and kerbside collection is inconsistent. With the likely destination being residual waste, recovering from incinerator ash is possible, but European Aluminium Association tests suggest that up to 60% of a thin film foil is lost (oxidised) during the process.[5]

Around **5.5 tonnes** of ore is required for every tonne of aluminium

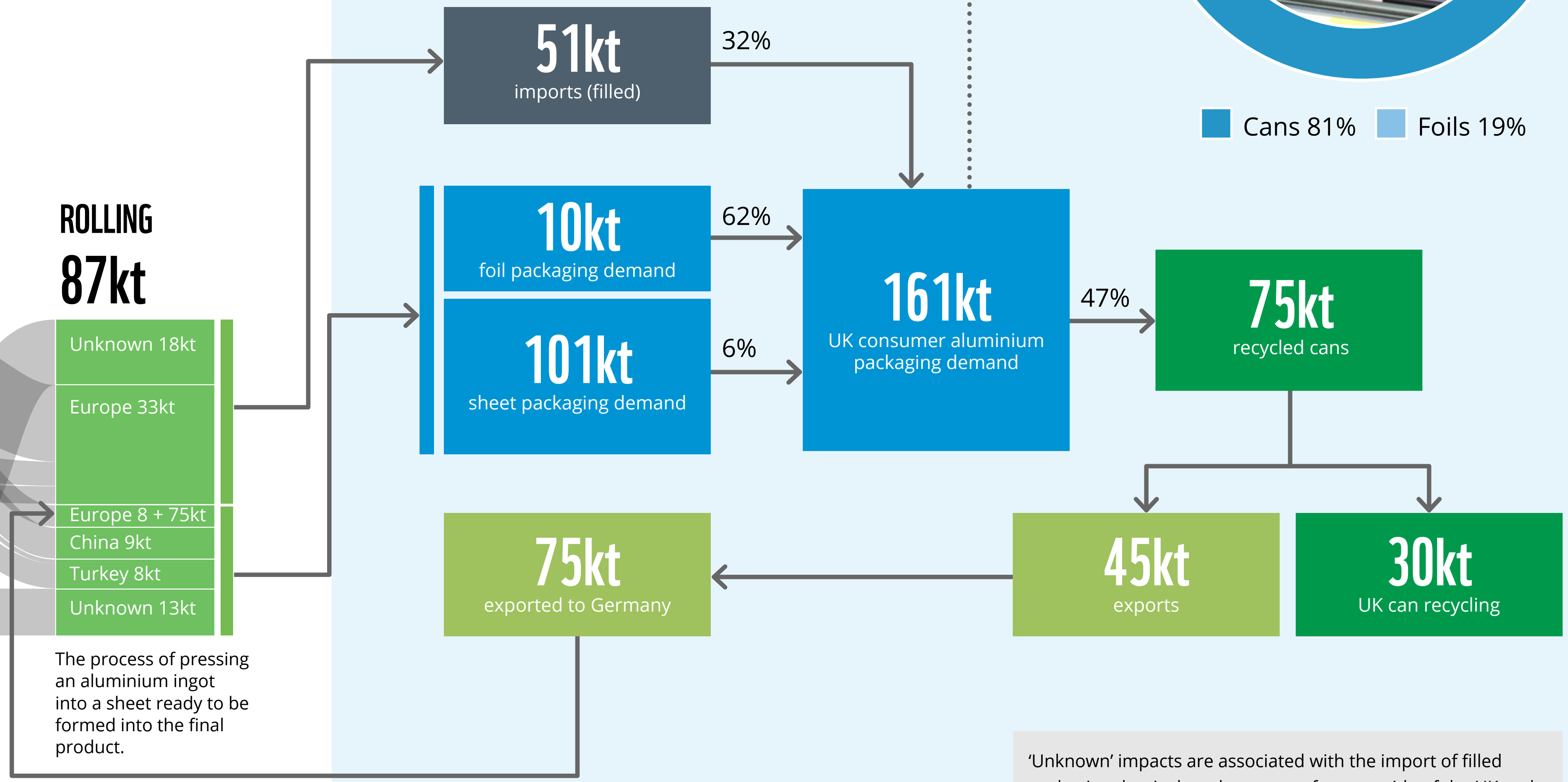


Bauxite is the principal source of aluminium and is found in topsoil (4-5 meters) typically located in equatorial regions. The ore is accessed by strip mining.

The process of removing impurities from the ore to produce aluminium oxide (alumina). This reduces the mass by around 65% and produces several residues including 'red mud' which is kept in large ponds.

A process that converts the alumina into large aluminium ingots by chemical reaction to remove the oxygen. It requires large amounts of electricity and is therefore typically located adjacent the purpose built power plants. The process further reduces the mass by around 50%.

The process of pressing an aluminium ingot into a sheet ready to be formed into the final product.



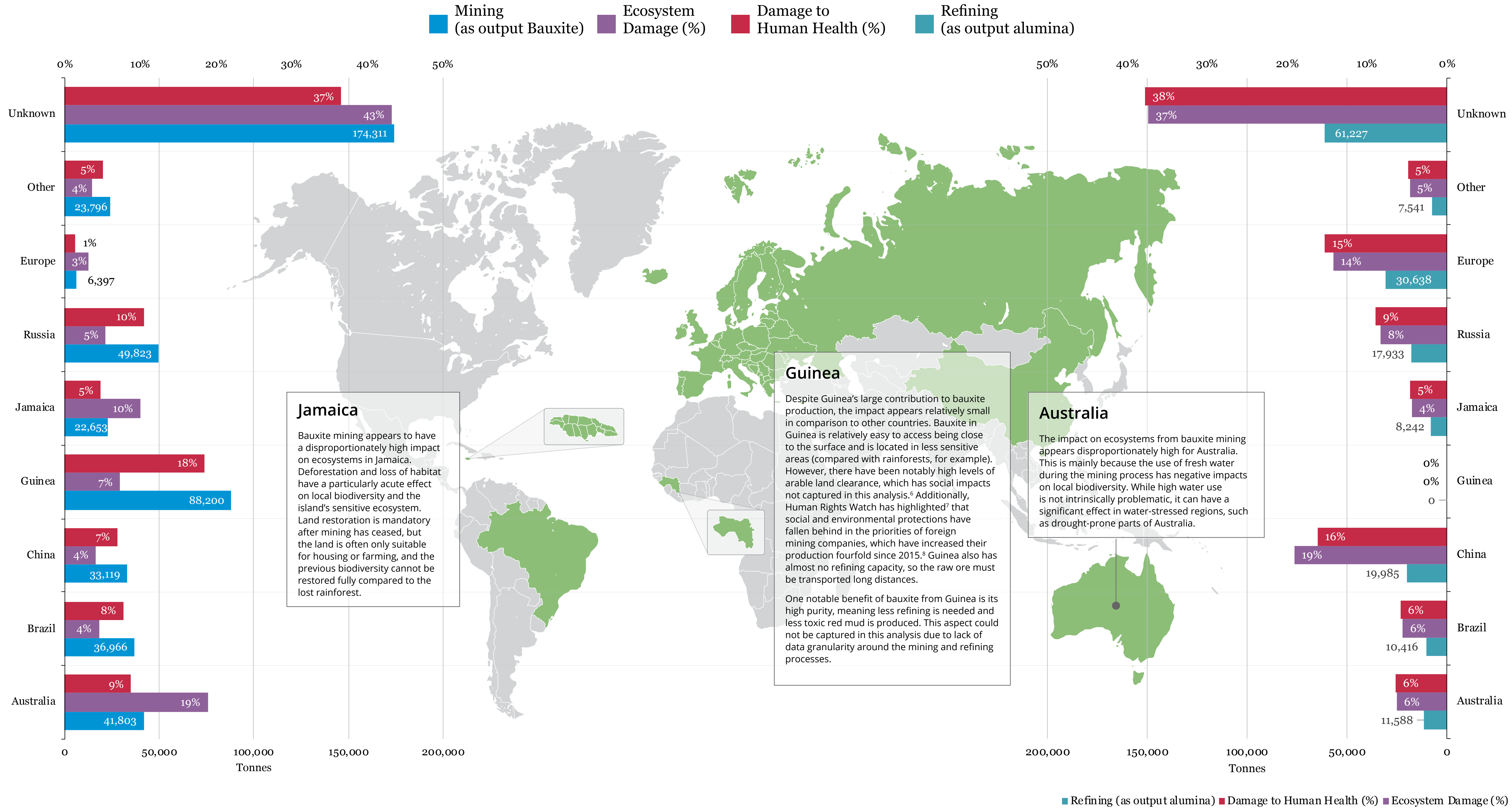
'Unknown' impacts are associated with the import of filled packaging that is thought to come from outside of the UK and EU and therefore may have differing supply chains.

ENVIRONMENTAL IMPACTS OF MINING AND REFINING ALUMINIUM

The extraction and refining of raw materials required to meet the UK's demand for virgin packaging aluminium has a range of impacts on ecosystems and human health.

As the graphs below show, bauxite mining has a disproportionate impact on ecosystems in certain countries, notably Jamaica and Australia. The mining of bauxite incorporates a spatial variation in the impacts on ecosystems to highlight the countries where the mining impact is disproportionately high to the activity taking place. This is particularly significant for land-use impacts on biodiversity, but also includes the effects of water use, air pollution and toxic chemicals on the surrounding area.

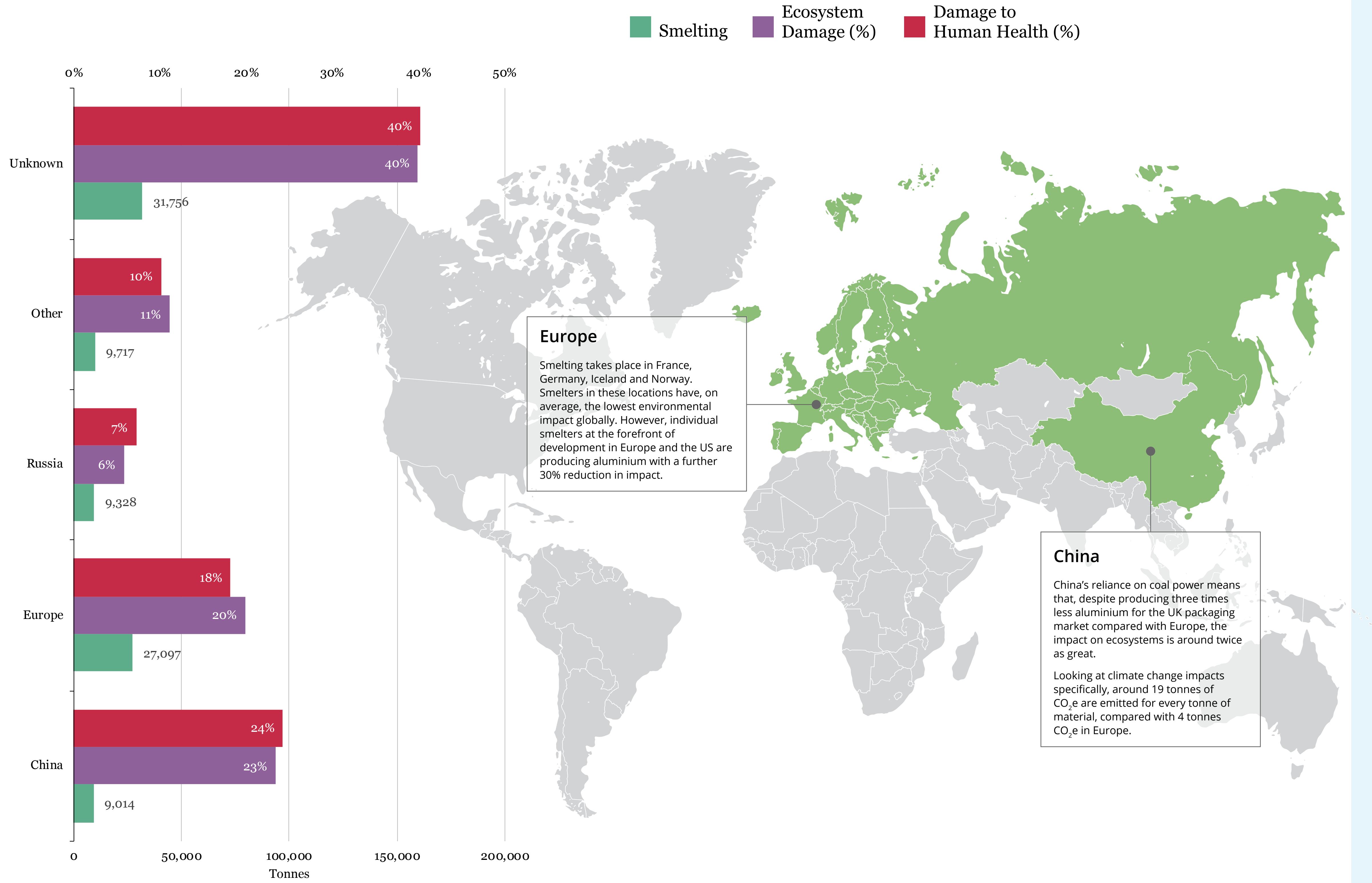
The impact of refining is largely even between countries, although in Asian countries, the higher proportion of coal in the energy mix increases the environmental impact. The human health impacts appear to be centred around 'red mud', a residue left over from the refining process that requires large and distinctive holding ponds. The data suggests a cancer risk from chromium in the red mud leaching into groundwater, but as yet, no specific literature references could be found to confirm this. Nevertheless, red mud does contain a cocktail of hazardous substances which are difficult to deal with.



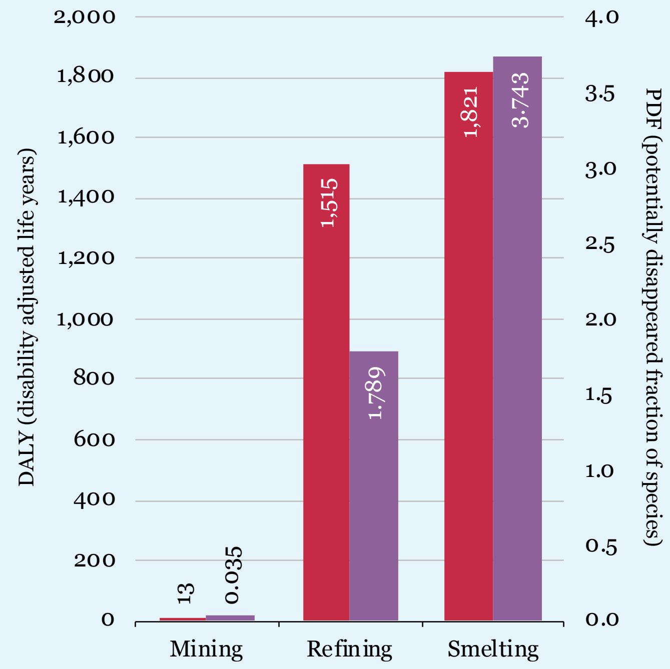
ENVIRONMENTAL IMPACTS OF SMELTING ALUMINIUM

Smelting is the most energy-intensive part of the aluminium process and uses vast amounts of electricity to fuel the reaction.

In much of North and South America and Europe, smelters are located close to hydroelectric power plants which supply the vast majority of their electricity. This contrasts with Asian countries (including China) and Australia, where most of the electricity comes from burning coal. While the construction of hydroelectric plants can have significant impacts on freshwater ecosystems and affected communities, the GHG emissions from coal power plants have a greater ongoing impact on ecosystems and human health. This is reflected in the results, which show that China has a disproportionally greater impact compared with the other source regions, which is almost entirely due to climate change impacts. The data should be considered relatively robust as it is published and regularly updated by World Aluminium for all the key regions.



Environmental Impacts Comparison by Production Stage



The overall impact is dominated by the refining and smelting processes. This means that, despite producing a relatively small amount of UK packaging aluminium, China is the largest contributor to its environmental impact due to the smelting process. Out of any packaging material, this is the single largest difference in geographical impact identified.

Although bauxite mining is a relatively minor contributor on a global scale, it has significant local impacts. These impacts are likely to vary depending on the mitigation measures that are in place locally but further investigation is required to determine whether such mitigation measures exist and what benefit they have.

4.0 STEEL

The packaging steel value chain has five broad stages:

1. iron ore mining
2. Blast furnace production of pig iron from iron ore mixed with coke and limestone
3. Production of crude steel from pig iron in a basic oxygen furnace (BOF) or from steel scrap in an electric arc furnace (EAF)
4. Casting and forming into sheet coils
5. Coating with tinplate or chromium

The production of a can uses one of two processes: either a modern process similar to aluminium can production where a stamped disc is drawn to form the bottom and side and the top is created separately (two-piece cans), or the more traditional process where the side is formed of a strip that is seam welded and the bottom and top are formed and attached separately (three-piece cans). A 'beader' is used to create a series of ridges in the wall that provides strength which enables thinner wall sections to be used, but also allows expansion and contraction during the canning process for hot fill or pasteurised products. Finally, various lacquers and/or varnishes are applied depending upon the application and whether the can is printed or paper covered. As with aluminium, these other materials are not currently accounted for in official recycling figures.

The total steel consumer packaging demand is calculated to be 332kt for 2018. Of this, an estimated 227kt of food cans were placed on the UK market in 2018 which is the equivalent of 4.3 billion cans.[9] Other consumer steel packaging accounts for a further 104kt and some 233kt of cans were reported recycled in 2018 which results in a 70% recycling rate for consumer steel packaging, of which 97% is recycled within the UK. This means the annual virgin material demand for UK consumer steel packaging is 98kt (~30% of 333kt). However, the UK recycles more steel cans than it produces, so recycling results in a net reduction in UK steel demand of 80kt. Unlike aluminium cans, steel cans do not need to be kept in a separate loop to maintain quality.

STEEL PACKAGING MATERIAL FLOWS INTO THE UK

The UK produces around half of the steel needed to meet its total consumer steel packaging demand, but the majority of this is exported: only 12% of UK steel is used to satisfy UK steel packaging demand. Around 20% of demand is imported as steel tinplate or electrolytic chromium-coated steel ready to be formed into cans, but the vast majority (68%) is imported as filled product. To reflect food supply chains, we assume that 65% comes from Europe and the remainder is classed as 'unknown'.

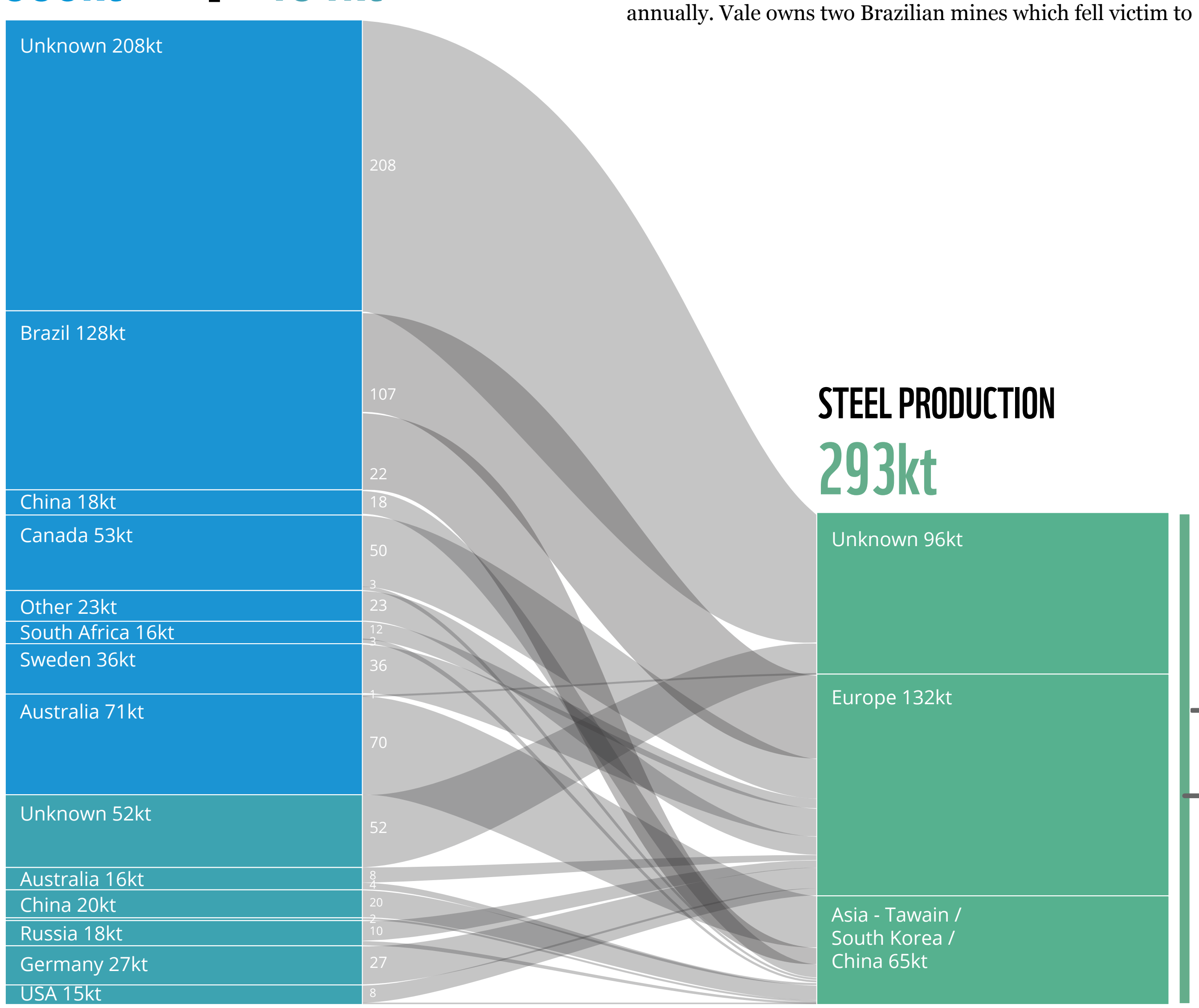
The two key material inputs – iron ore and coking coal – are tracked to the originating countries; the diagram below shows the main sources of iron ore. The biggest single supplier of ore is Brazil, which is the principal ore supplier to most European countries. The UK's ore requirement from Australia comes via steel packaging imports from Asia.

The largest iron ore mines in Brazil are owned by Vale, who along with Rio Tinto and BHP group are the largest producers of iron ore in the world, each with around 300 million tonnes annually. Vale owns two Brazilian mines which fell victim to dam failures in recent years with the Mariana dam disaster in 2015 and the Brumadinho dam disaster in 2019. Both incidents involved the failing of a tailings dam – a structure used to indefinitely store hazardous waste from iron ore mining operations. While Vale paid significant reparations for the loss of life, the environmental damage to local water ecosystems will take many years to recover. There is also little regulation or standardisation in how tailings dams are constructed in Brazil or elsewhere, which means that failures are common in many countries (although the death toll from the two Vale failures was exceptional).

The UK currently recycles more steel packaging than it produces for the UK market (233kt vs 147kt). This means that there is no net requirement for UK produced virgin steel and less raw material is needed for other UK steel products. This in turn reduces the need to extract coal from Ffos-y-fran, one of the last remaining open cast coal mines in South Wales, which sends its coal to the nearby Port Talbot plant. However, since most steel is imported, there are significant impacts associated with steel production from other countries.

Around **2** tonnes of iron ore and **0.5** tonnes of coking coal is required for every tonne of steel

IRON ORE MINING 553kt + **COKING COAL** 151kt

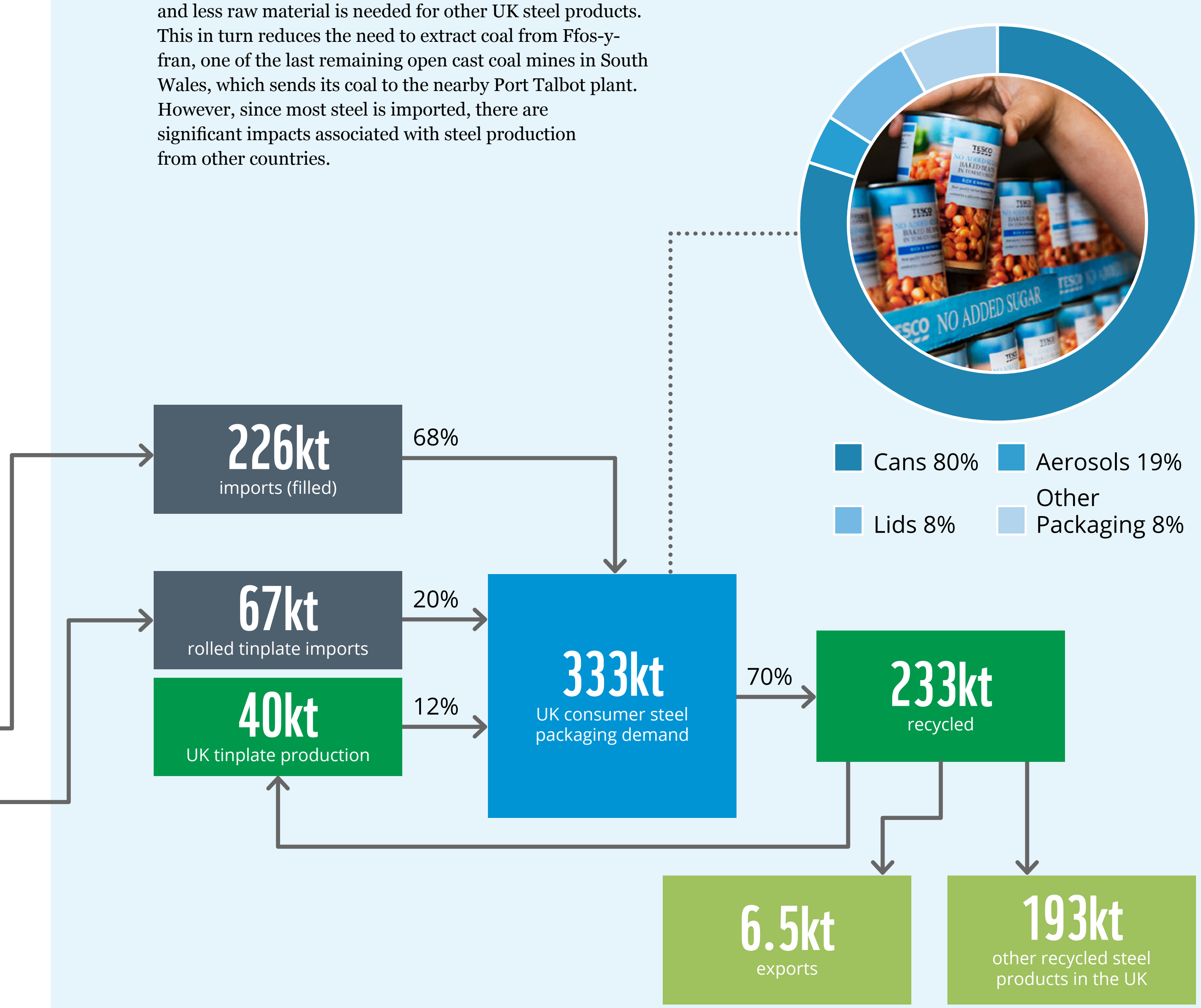


Mined in open cast mines from varying types of rock. Depending on where this takes place it may require beneficiation to increase the iron concentration.

Mined in both open cast and deep mines, this coal is specific to the steel production industry. Once mined, it is baked without oxygen which makes it more chemically reactive in iron making blast furnaces.

The process involves two steps; smelting of the ore with coking coal to produce iron, and steel production with heat and oxygen to reduce the carbon content to the required level.

The process of pressing steel into a sheet ready to be formed into the final product. The sheets are often plated with tin (tinplate) or chromium (ECCS) in the same plant.

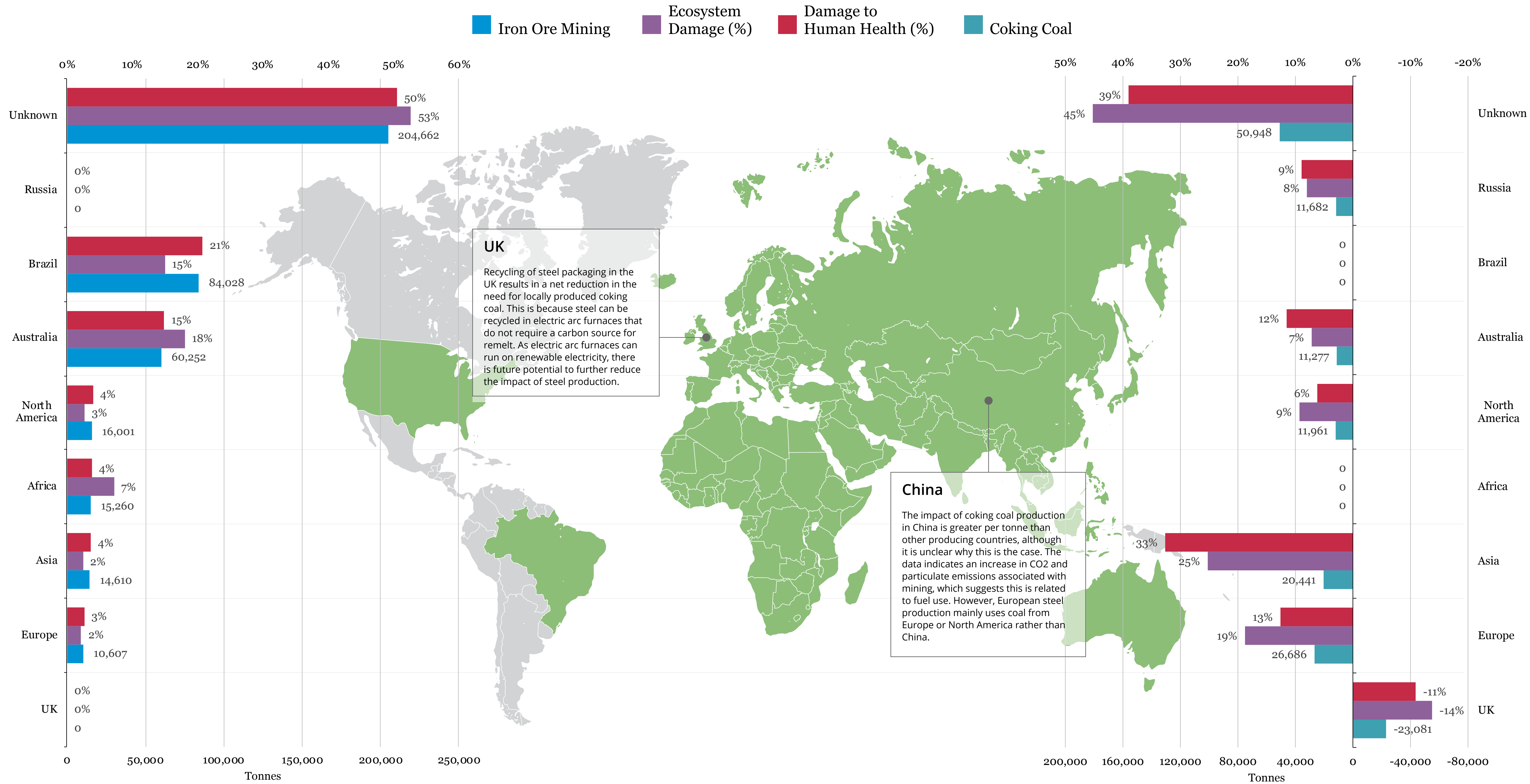


'Unknown' impacts are associated with the import of filled packaging that is thought to come from outside of the UK and EU and therefore may have differing supply chains.

ENVIRONMENTAL IMPACTS OF IRON ORE AND COKING MINING

Brazil and Australia are the main suppliers of iron ore. Although there appears to be relatively little difference in the modelled ecosystem impacts, no primary data on the impacts of mining in different countries is available so it is unclear whether practices differ significantly between regions.

Extraction of coking coal has a larger overall impact despite requiring four times less material than iron ore. Data for coal extraction in different regions suggests that coal from China has the highest impact on human health, particularly from particulate matter and contact with toxic substances, both of which are local effects likely to impact workers and communities. This is likely due to burning of coal for energy locally. Australia also suffers in this area. For ecosystem impacts, along with climate change there are issues with freshwater eutrophication, particularly in Australia. Canada appears to show the lowest ecosystem impacts overall.



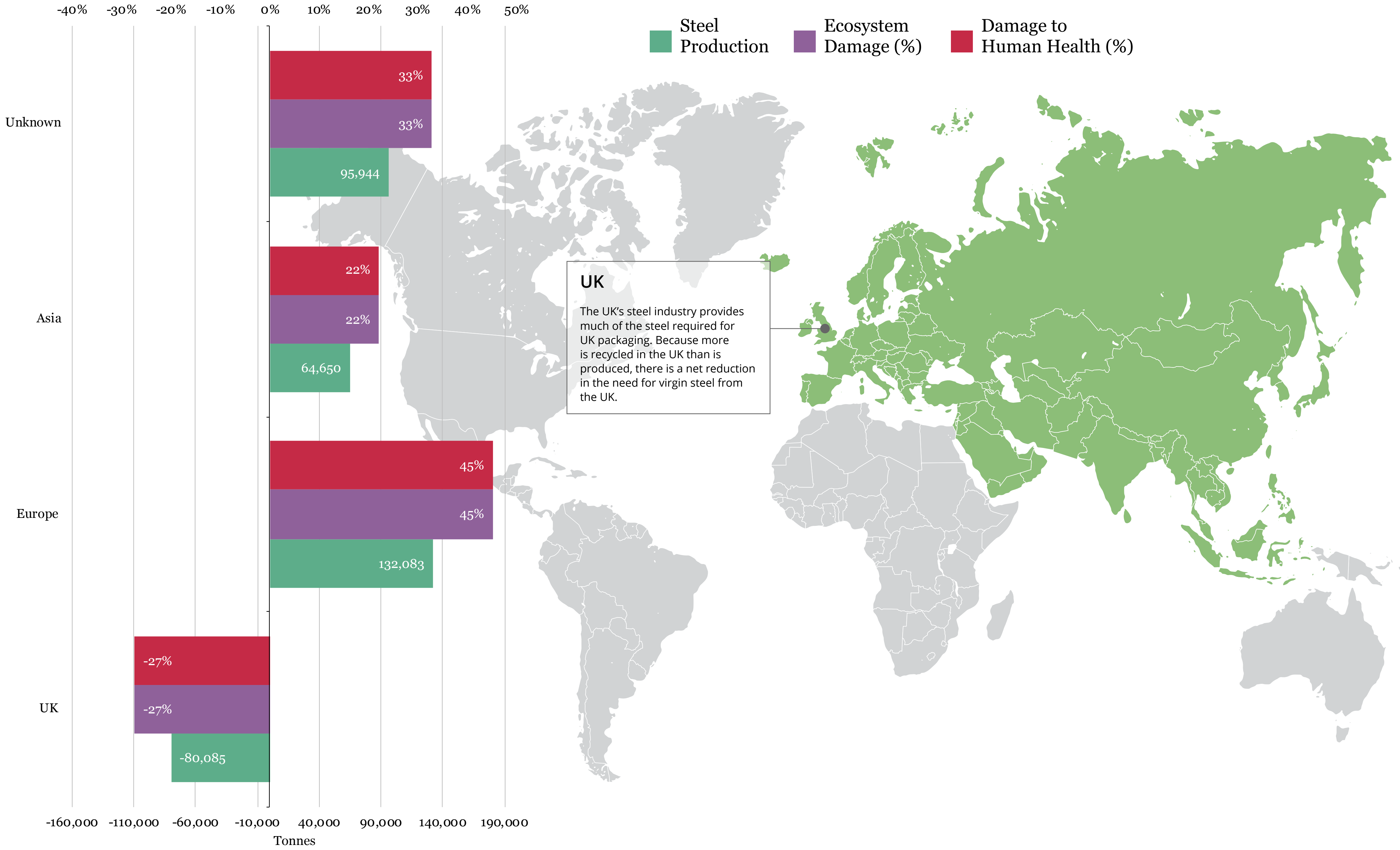
ENVIRONMENTAL IMPACTS OF STEEL PRODUCTION

The steel production process is centred around Europe and Asia. There is no data available on the impacts in different locations. As the main impact is the burning of coking coal, this is likely to be similar regardless of location. However, steel sourced from China is likely to use coking coal from China or Australia, which itself has a comparatively larger impact.

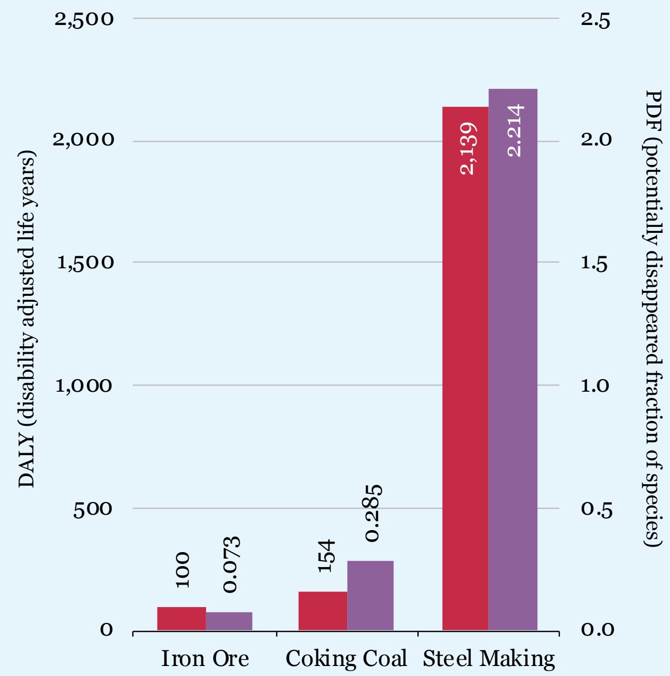
The steel production process is far less energy intensive compared with aluminium, and while heat energy is needed, this is produced by the coking coal during the iron-making process. The coke is also an intrinsic part of the chemical reaction that takes place so cannot simply be replaced with other heat energy sources. This means that, from a greenhouse gas emissions perspective, where the manufacturing takes place is less important as the emissions from burning coking coal will be similar regardless of location.

Alternatives to coking coal such as plastic waste or biomass have their own limitations and are not typically seen as a full replacement for coke. Additionally, burning plastic only provides a short-term solution to the problem of plastic waste and still produces considerable carbon emissions. Hydrogen is also a potential replacement (with water vapour as the only emission) but is not commercially proven. The large-scale production of hydrogen is also challenging, particularly as it is often seen as the solution to a number of other heat energy requirements.

Despite these challenges, the first commercial hydrogen powered facility is due to enter into operation from 2024 and produce up to 5 million tonnes of steel in Sweden by 2030 – doubling Sweden's current capacity and aiming to use local iron ore deposits that are mostly exported currently.[10] The cost is likely to be significantly more than traditional steel, but could be offset by increasing the price of carbon emissions and the expected efficiencies from a large-scale roll-out of hydrogen production over the next decade.



Environmental Impacts Comparison by Production Stage



Steel production is the dominant process although, as with aluminium, the mining of ore and coal will be responsible for localised impacts, particularly considering the relatively frequent accidents. At this time, there is no way to quantify the human and environmental cost of such disasters; they are, however, not inherent to the activity but a result of poor practices that can be rectified. The extraction of coking coal is also more impactful than mining iron ore, despite requiring significantly less tonnage.

5.0 GLASS

Soda-lime glass, also called soda-lime-silica glass, is the principal material used for glass containers, including bottles and jars. Silica sand is a mineral which occurs naturally in certain locations and is extracted through mining and quarrying, as opposed to dredging of regular building sand which is not pure enough (<95% silica) to be used for glassmaking. Although sand is relatively inexpensive to extract and simple to process, it is a heavy material so is expensive to transport.
As a result, industries which rely on sand, such as the glass industry, are normally located close to where the sand is extracted.

The other key materials for glass production are lime and soda ash. As these materials are also used for a number of other applications, the trade flows are very complex and difficult to track. However, most glass-producing countries also produce soda ash and the supply chains are thought to be similarly localised.

After raw material extraction, there are four typical stages in the glass container manufacturing process which all take place in the same factory:

1. Batch preparation: the raw materials are mixed with additives which determine colour or specific chemical and physical properties. Coloured glass involves the addition of metal. Copper compounds for instance are used to make blue, green and red glass. Recycled glass, or cullet, is also added at this stage
2. Melting and conditioning: the raw materials are heated in a furnace at temperatures up to 1,700°C
3. Forming: the molten glass is streamed down feeder channels or 'forehearths' operating at 1,050-1,200°C. The forehearths discharge the glass into forming machines where it is pressed or blown, using compressed air, into shape
4. Annealing: rapid temperature changes can cause internal stress within the glass. The annealing process removes these stresses by reheating the glass to 400-600°C, followed by controlled cooling

The UK's total glass packaging demand was an estimated 2,488kt in 2018. Around 1,700kt of glass packaging was reported as sent for recycling in 2018, which results in a recycling rate of 68%. However, some of this glass is used for low-grade applications such as aggregate substitute. If we only consider glass that is remelted and used in place of virgin material, the recycling rate is reduced to 55% – this is the figure used in this analysis. Assuming a 55% recycling rate, the 2018 UK net demand for virgin glass was 1.1 million tonnes.

British Glass reported that the average post-consumer recycled content of container glass was 38.5% in 2016[11] which results in 770kt of recycled content being used in the 2mt of UK produced container glass. With 962kt of container glass being recycled for remelt within the UK. This suggests a higher recycled content of 48%, but it is likely that remelted container glass will also be used in other non-packaging applications where collection and recycling is less common. A significant proportion of post-consumer glass is also exported for remelt, mainly to Portugal and Belgium.

GLASS PACKAGING MATERIAL FLOWS INTO THE UK

In 2018, 45% of UK packaging glass demand was produced in the UK. Imports of unfilled glass packaging are responsible for 9% of demand with 82% of this coming from Europe. France, Germany, Bulgaria and Italy are responsible for 27%, 15%, 12% and 8% respectively.

The UK is nearly self-sufficient in silica sand, producing 1.4 million tonnes in 2018, of which an estimated 634kt was used for containers. Only six locations in the UK produce silica sand suitable for the manufacture of colourless glass containers, with the open-cast mines concentrated mainly in the northwest and northeast of England, and West Lothian in Scotland. Silica sand is of much higher purity than sand used in construction, so dredging or removal from coastal areas would not produce a suitable material.

Silica resources for glass production are chiefly found in the Netherlands, Germany, Poland, Czechia and the UK, as well as Italy, France, Spain, Bulgaria and Belgium. The top three countries from which the UK imports unfilled glass containers – France, Germany and Bulgaria – have both glass manufacturing and silica sand extraction operations. In France, for instance, 95% of the raw materials used by the glass industry are produced domestically.

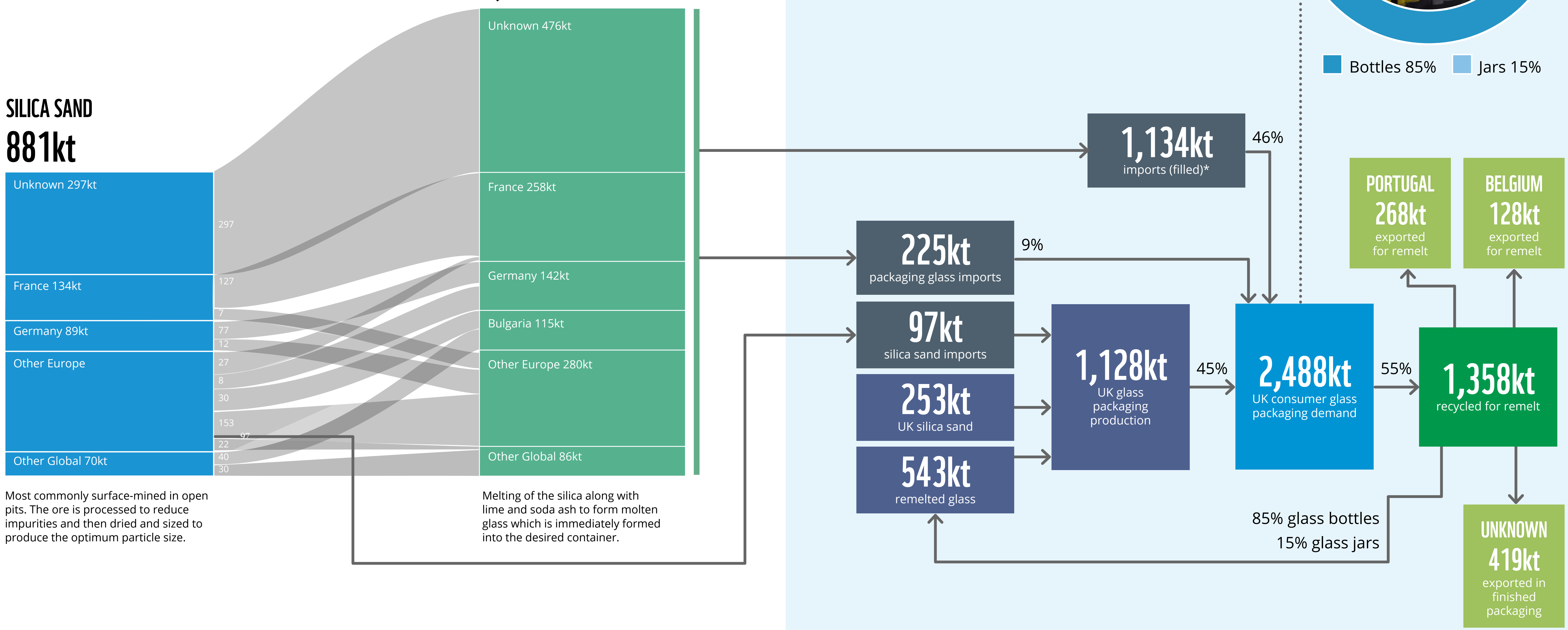
The UK imported 1,358kt of filled glass packaging in 2018, accounting for 46% of demand. Reflecting food supply chains, we assumed that 65% comes from Europe and classed the remainder as 'unknown'. This means that although the glass packaging industry is relatively localised, imports of filled glass products could come from much further away, but there is no way of determining this at present.

Of the 1,350kt of glass collected for recycling, 396kt is exported for remelt, of which 96% goes to Belgium and Portugal. While Belgium is responsible for 5% of glass imports into the UK, none is directly imported from Portugal; for both countries this results in a net material gain from the UK.

'Unknown' impacts are associated with the import of filled packaging that is thought to come from outside of the UK and EU and therefore may have differing supply chains.

Around **1.2** tonnes of raw material is required for every tonne of glass

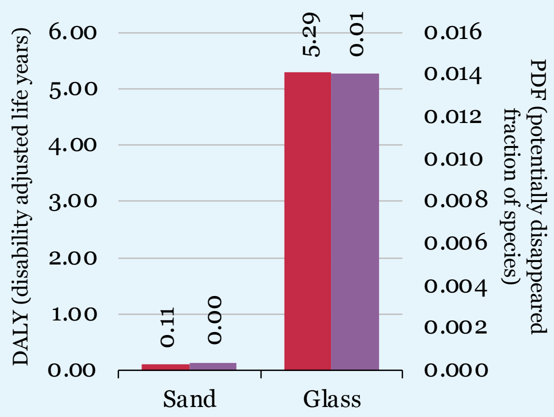
GLASS PRODUCTION
1,357kt



ENVIRONMENTAL IMPACTS OF GLASS

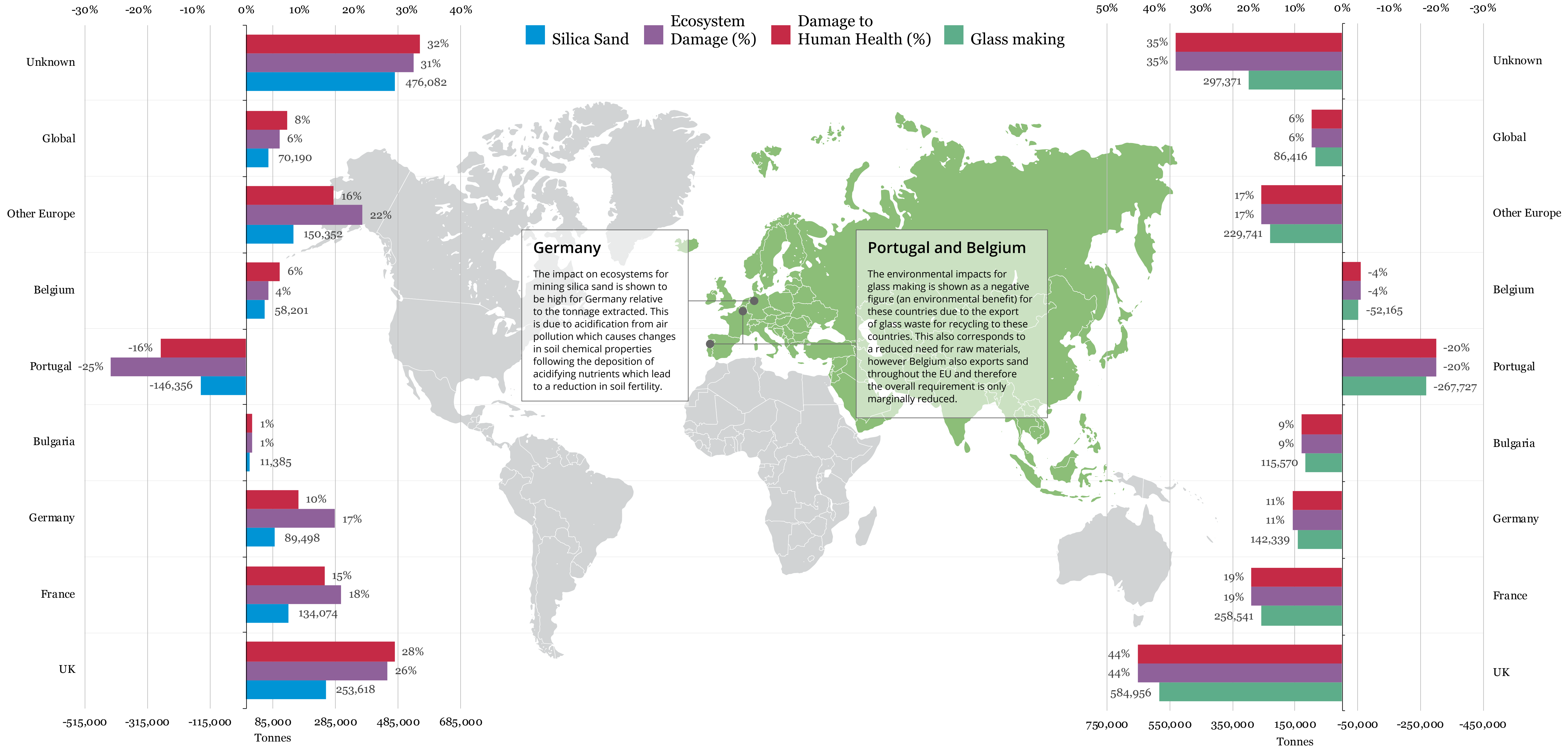
As we focus on the largest environmental impacts, some impacts from processes and raw material acquisition that may take place in other countries (e.g. production of soda ash and lime) are assigned to the primary country for the purposes of this analysis. In general, though, the supply chain for glass is very localised. The transportation of finished glass packaging is a significant contributor to its overall impact due to the typically high weight. Although this is out of the scope of this study, reducing weight is a key design recommendation as this reduces the impact associated with both material extraction and the transport of the finished product.

Environmental Impacts Comparison by Production Stage



For the glass production itself – which dominates the overall impact – country-specific data does not exist but there is likely to be very little difference between European and UK production. The main impact comes from the extremely high heat requirement to melt the sand, which comes primarily from natural gas. However, a 10% increase in recycled material reduces the furnace heat requirement by 2.5%. So while remelting glass still has a relatively high heat requirement, the need for virgin raw material is reduced and the impacts reduced overall.

Other glass plants outside Europe, particularly in Asia, may use coal for heating, which would significantly increase the impact, but this would apply only to imports of filled packaging whose origin cannot be confirmed currently.



6.0 PAPER AND CARD

Producing virgin pulp for papermaking involves the following steps:

1. Wood is logged, debarked and chipped: bark that cannot be used in papermaking is removed and burned for energy. Stripped logs are chipped into small pieces
2. Pulping: water and heat are added and the wood is separated into individual fibres by either chemical or mechanical processes. Chemical pulping provides a strong paper suitable for printing paper, packaging and cardboard. Mechanical pulping generally gives higher yields but weaker paper, mainly used for hygiene paper and newsprint
3. Papermaking: the pulp is diluted with water and can also be blended with different pulps and chemicals. The fibre liquid is formed into sheets, pressed and dried

Pulp production can be integrated into papermaking or carried out as a separate activity. An integrated mill produces paper on site, while a non-integrated mill dries and presses pulp before transporting it to a paper mill.

The UK's total paper packaging demand was an estimated 5,062kt in 2018. The UK both imports and produces paper packaging. Imports arrive in four forms: paper or board ready to be converted (18%), pre-made packaging ready for filling (47%), filled packaging ready for sale (7%), and pulp for use in UK mills combined with UK-grown wood (27%).

Some 3,670kt of paper packaging was reported as recycled in 2018. Around 36% of this was recycled in the UK with the rest exported, primarily to China and other Asian countries, with less than 10% remaining in Europe. This means that the majority (64%) of reported recycled paper cannot be verified and is transported into a different paper supply chain. With only around 1% of UK paper packaging coming from China, recycling is largely a one-way trip.

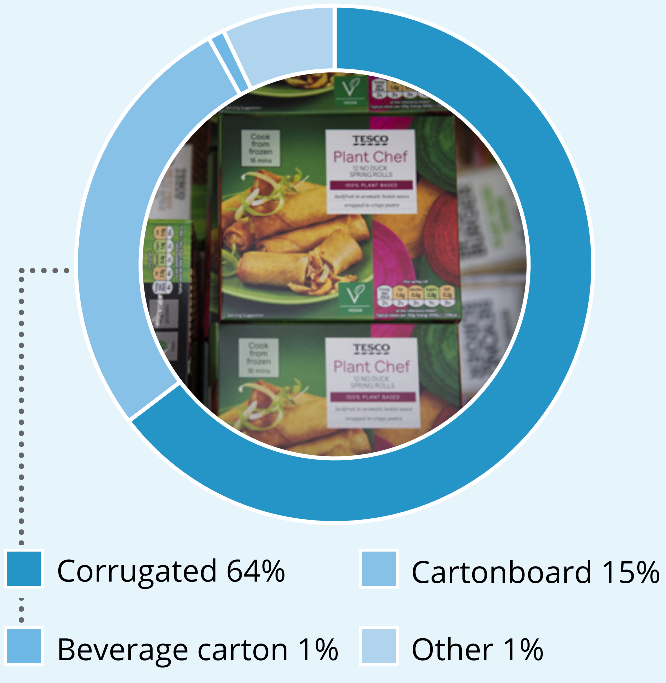
Recovered paper and card packaging is used mainly in the production of new board and cardboard products and is, to a certain extent, circular in the UK. The exception is liquid beverage cartons which require virgin fibre for structural integrity, but only represent 1% of the paper and board packaging market. The paper industry reports that UK paper and board typically includes around 70% recycled content, which matches closely with the relative proportions of reported UK recycling (1,352kt) to production (1,904kt), although some production losses would be expected during recycling. Imports vs exports are similarly balanced, with around 73% of paper and pulp products being imported and 64% of recycling being exported. To export less would require an expansion of the paper industry in the UK.

PAPER AND CARD PACKAGING MATERIAL FLOWS INTO THE UK

The UK has 47 paper mills, but only two are integrated mills that manufacture paper directly from UK-sourced wood. Virgin chemical wood pulp (hard and soft) imported into the UK is predominantly sourced from Sweden and Brazil. Sweden and Finland represent over 80% of the UK's paper packaging raw material demand. with their pulp and paper industries mainly using wood from domestic forests. However, both countries also import small proportions of chemical pulp from Brazil, and wood from within Europe, including Norway, Russia and Latvia. Germany provides the third largest supply of paper from the EU and has felling, pulp and papermaking capacity, although it also imports pulp from Sweden and Finland as well as Brazil – the majority of Brazilian pulp enters the UK value chain via Germany. Asian countries only feature as waste export destinations, with China, India and Indonesia being the main export destinations for UK wastepaper.

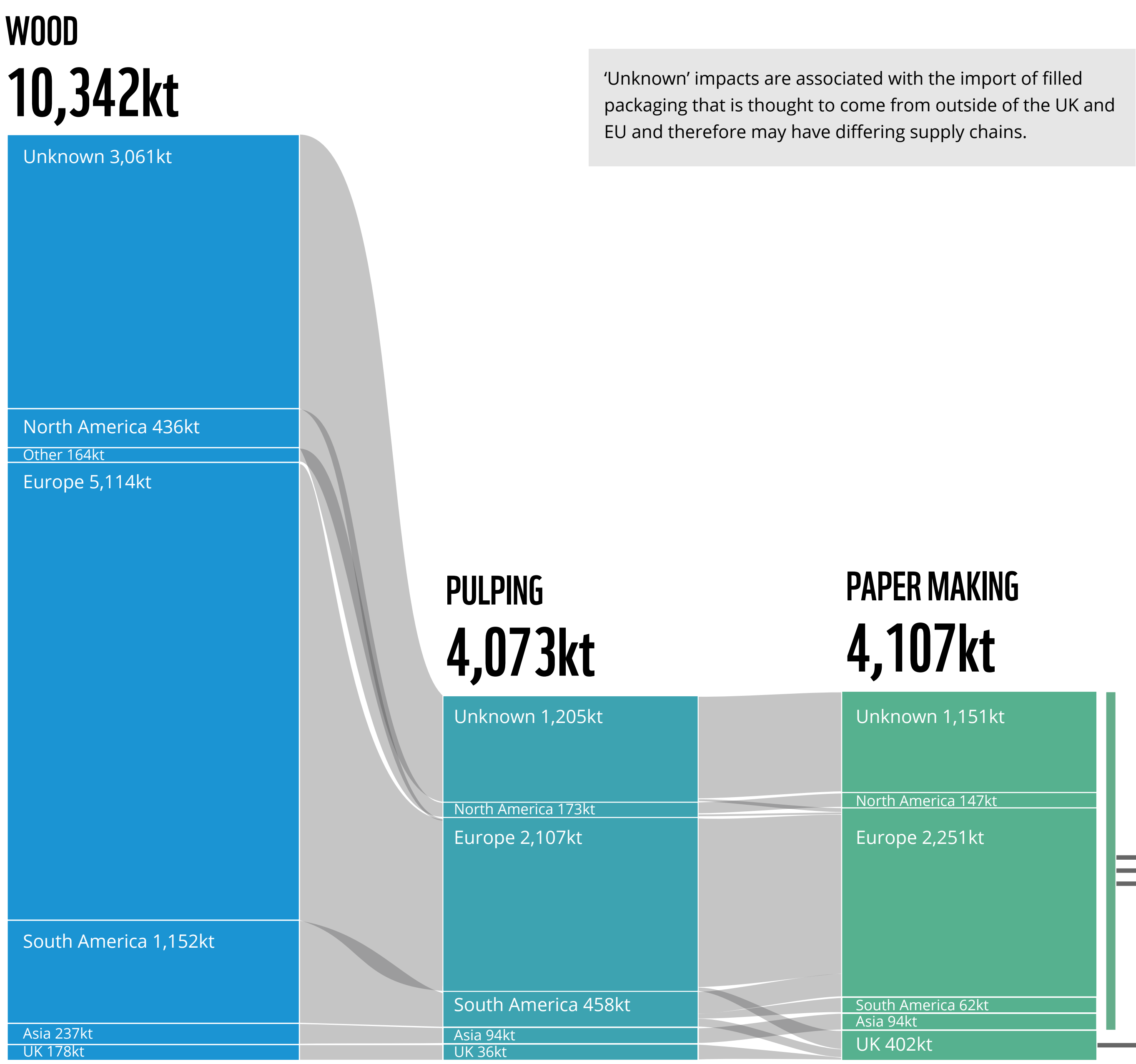
The only stage in the production process for which we are able to show regional variation in ecosystem impacts is the growing and felling of trees. The entire ecosystem impact is associated with land use, and shows a disproportionate impact in South America (primarily Brazil). Despite Sweden and Finland being responsible for the largest proportion of the forestry operations, the data suggests these are less sensitive areas for land use so the impact is very low.

For pulping and papermaking, there is no data for countries outside Europe so the impacts are shown to be the same regardless of location. Outside of the EU, South America is the only significant pulp and papermaking region found to be supplying the UK, but it is unclear whether the practices differ from the UK or Europe.



'Unknown' impacts are associated with the import of filled packaging that is thought to come from outside of the UK and EU and therefore may have differing supply chains.

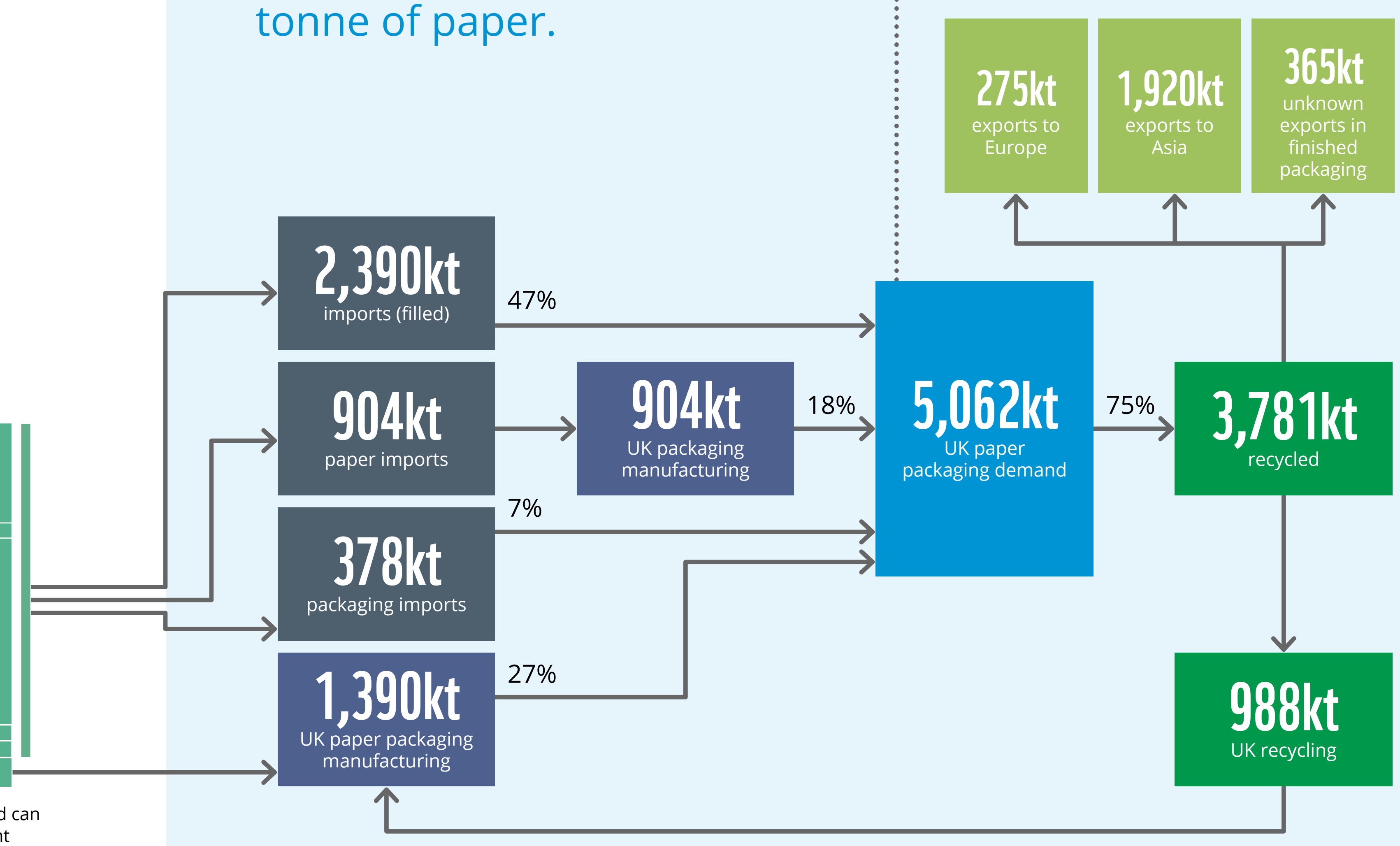
Around **2.5** tonnes of wood are needed for every tonne of paper.



Wood is logged, debarked and chipped

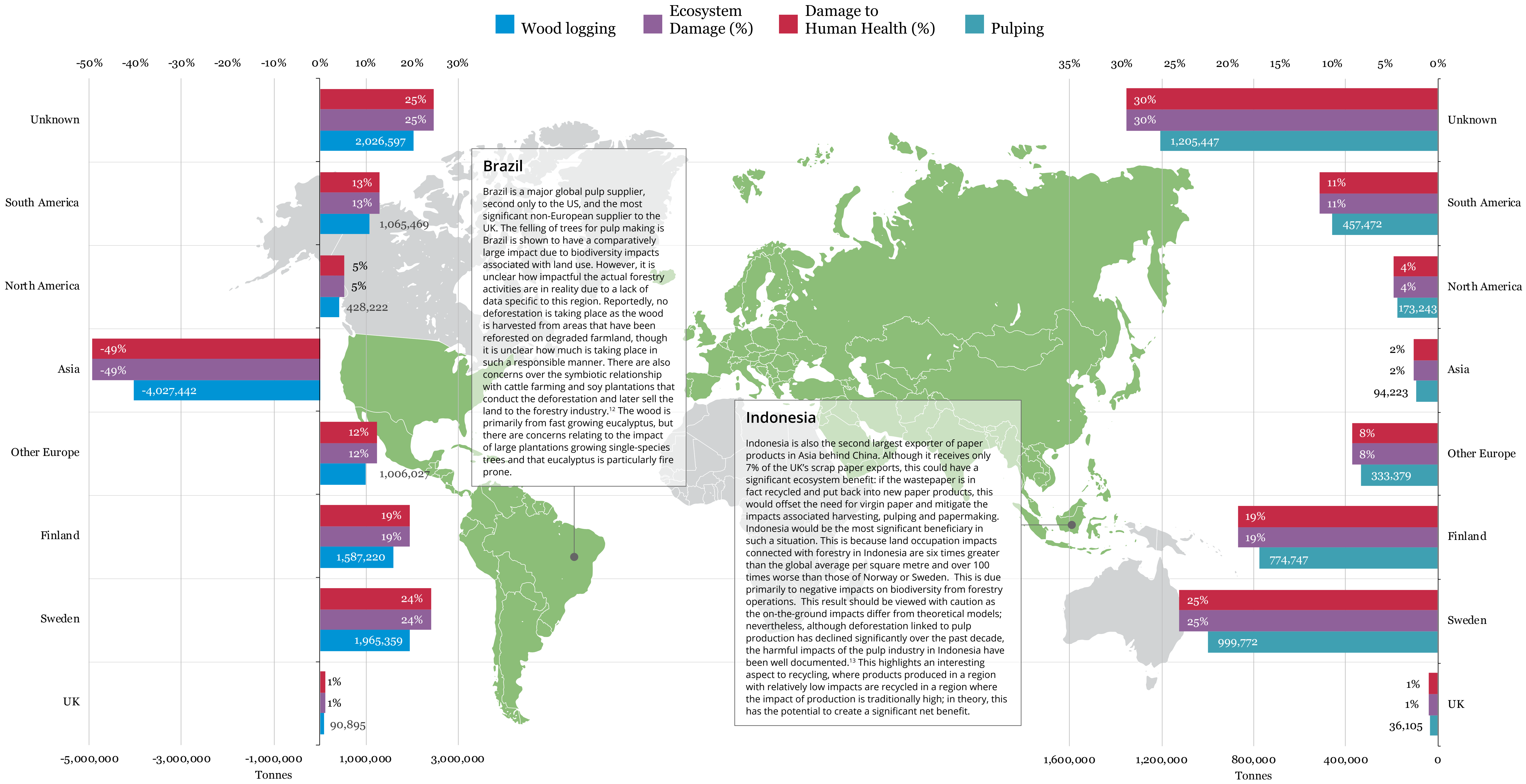
Water, heat and chemicals are added and the wood is separated into individual fibres by either:

Pulp is diluted with water and can also be blended with different pulps and chemicals. Sheet are formed by pressing and drying.



ENVIRONMENTAL IMPACTS OF WOOD LOGGING AND PULPING

Sending UK paper scrap to Indonesia, India and China for recycling may offset significant ecosystem impacts by reducing the need to harvest virgin wood if the exported material is used as recycled content. Human health impacts are mostly associated with climate change and particulate matter, likely through burning of fuel for energy. Pulping also results in human health impacts due to the release of toxic heavy metals into the air, although these impacts will depend upon the exact pulping process and the local restrictions in place for chemical use and release. Water use is typically high for much of the paper making process, but the industry is not centred on water stressed areas which means the impacts are likely to be comparatively low; however the lack of regional specific data means this cannot be confirmed. Similarly, wastewater effluent is known to contain nutrients such as phosphorus that can increase eutrophication (the effects of this include increase in algal growth and the subsequent unbalancing of ecosystems). With strict controls on effluent in Europe (and the background data coming from Europe), the relative impact is shown to be low, but again, this cannot be confirmed outside of Europe. The strength of local regulation on chemical use and effluent release will have a large impact on how important the impacts on local biodiversity will be.



Brazil

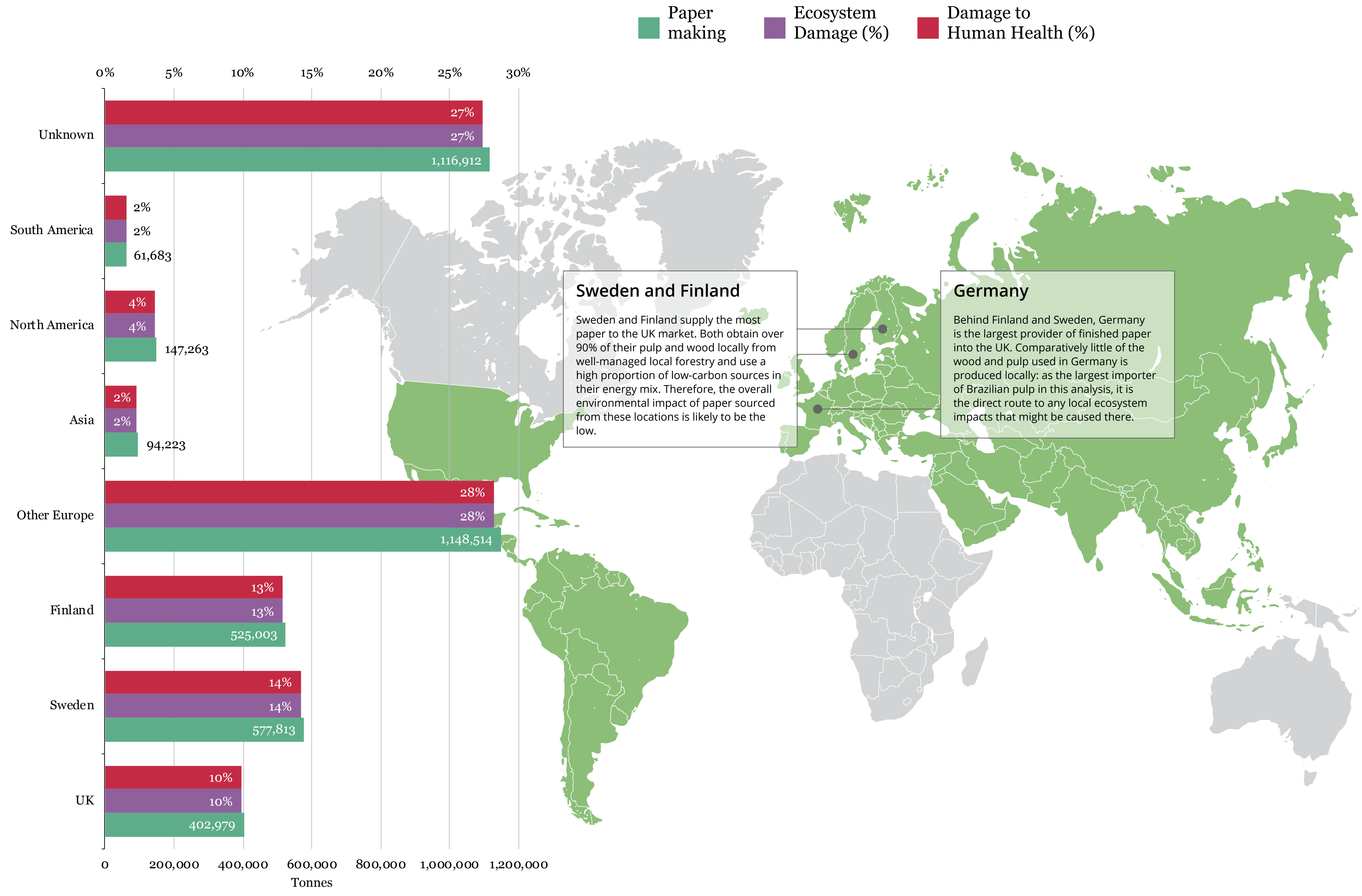
Brazil is a major global pulp supplier, second only to the US, and the most significant non-European supplier to the UK. The felling of trees for pulp making is Brazil is shown to have a comparatively large impact due to biodiversity impacts associated with land use. However, it is unclear how impactful the actual forestry activities are in reality due to a lack of data specific to this region. Reportedly, no deforestation is taking place as the wood is harvested from areas that have been reforested on degraded farmland, though it is unclear how much is taking place in such a responsible manner. There are also concerns over the symbiotic relationship with cattle farming and soy plantations that conduct the deforestation and later sell the land to the forestry industry.[12] The wood is primarily from fast growing eucalyptus, but there are concerns relating to the impact of large plantations growing single-species trees and that eucalyptus is particularly fire prone.

Indonesia

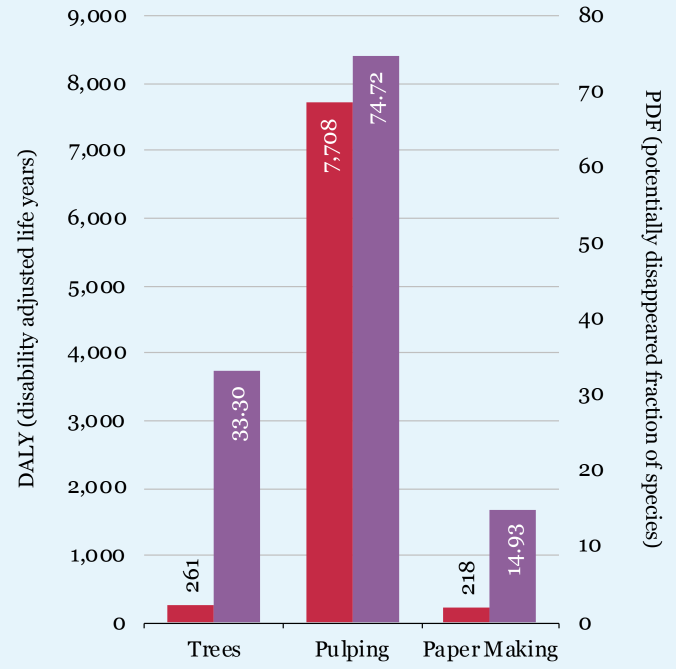
Indonesia is also the second largest exporter of paper products in Asia behind China. Although it receives only 7% of the UK's scrap paper exports, this could have a significant ecosystem benefit: if the wastepaper is in fact recycled and put back into new paper products, this would offset the need for virgin paper and mitigate the impacts associated harvesting, pulping and papermaking. Indonesia would be the most significant beneficiary in such a situation. This is because land occupation impacts connected with forestry in Indonesia are six times greater than the global average per square metre and over 100 times worse than those of Norway or Sweden. This is due primarily to negative impacts on biodiversity from forestry operations. This result should be viewed with caution as the on-the-ground impacts differ from theoretical models; nevertheless, although deforestation linked to pulp production has declined significantly over the past decade, the harmful impacts of the pulp industry in Indonesia have been well documented.[13] This highlights an interesting aspect to recycling, where products produced in a region with relatively low impacts are recycled in a region where the impact of production is traditionally high; in theory, this has the potential to create a significant net benefit.

ENVIRONMENTAL IMPACTS OF PAPER MAKING

As with forestry and pulping, there is limited country-specific data on the impacts of papermaking. Data is primary available as a European average, so the results might not be fully representative of countries outside Europe. Both human health and ecosystem impacts are associated primarily with climate change. Because of this, factors such as the carbon intensity of the electricity grid and methods of heat generation during the drying process are likely to drive the most significant differences in impact between countries. As chemical usage is most strongly associated with the pulping process, papermaking itself is less influenced by local regulations on chemical use.



Environmental Impacts Comparison by Production Stage



Notwithstanding the potential for pulpwood to be grown in an environmentally beneficial way (in contrast to non-renewable resources), the raw material extraction stage is a more significant stage from an ecosystem perspective for paper and card than any other material in the analysis. This is because the downstream manufacturing processes are less energy intensive than for other materials, particularly metals, and because the impacts of land use on biodiversity have the potential to be significant. This is particularly the case outside Europe.

The largest impacts of the pulping process come from energy and chemical use. The papermaking process itself is relatively low impact and consists primarily of using heat to dry the paper.

7.0 PLASTIC

Plastics are comprised of polymers typically synthesised from petrochemicals – crude oil, natural gas or coal. Plastic can also be made from carbohydrates, vegetable fats and oils, and starch. Globally, nearly all plastics (97-99%) are fossil-based, with the remaining 1-3% bio-based.

The plastic supply chain consists of six typical stages:

1. Mining and extraction of oil and gas
2. Refining to produce hydrocarbons e.g. naphtha
3. Cracking hydrocarbons to produce monomers and other chemical products
4. Polymerisation of monomers to form polymers, such as polyethylene
5. Compounding with various additives and colours to produce the desired plastic material
6. Forming the plastic product through moulding processes

Raw material acquisition for fossil-based plastics involves the mining and extraction of oil, natural gas and coal. These are refined into hydrocarbons such as naphtha (from crude oil), which is the source of several monomers relevant for the plastic supply chain, including ethylene and propylene.

In the polymerisation stage, monomers are joined together to form long chains called polymers. Polymers are almost never sold into products on their own as their performance for various applications needs improving with various additives. Chemicals and compounds used to improve the physical properties of the plastic include plasticisers in PVC to make it softer and more flexible, fillers such as glass fibre to increase strength and stiffness, and additives to increase UV stability, add colour, or make the plastics easier to process. These are present in many plastics in the range of 0.5-3% depending upon requirements, although glass fibres and other fillers can make up over 50%.

Additives may have downstream effects on recycling. Fire retardants, for example, can make the material hazardous or uneconomical to recycle, though this is generally not the case for packaging plastics. Food packaging in particular must adhere to strict regulations designed to prevent anything hazardous being used if it can migrate into food; it is also often made from clear plastic which limits what can be added. PET bottles will typically contain small amounts of UV stabilisers and oxygen scavengers (antioxidants) which are designed to increase the shelf life of contents; these typically make up less than 1% of the plastic.

Plastics are then formed into finished or semi-finished products, including packaging, through processes such as injection or blow moulding. The stages of this production process can happen in one country or across various geographic locations.

The UK's total plastic packaging demand is estimated at 2.34 million tonnes for 2018. Consumer packaging (1.48mt) and hospitality (225kt) make up a total of 1.7 million tonnes. Other non-consumer (commercial & industrial, construction and demolition and agriculture) plastic packaging is excluded from this study. Of the 2.34 million tonnes, a reported 1 million was collected for recycling in 2018. This results in a reported recycling rate of 44%. Unlike other materials, however, plastic is not categorised by type so it is unclear how much of it would be returned into new packaging. Also, a large proportion is exported to countries outside Europe with no verification that recycling is taking place. This, combined with processing losses from the plastic recycling process, means the true recycling rate for plastic packaging is likely to be significantly lower, and recycling back to packaging lower still.

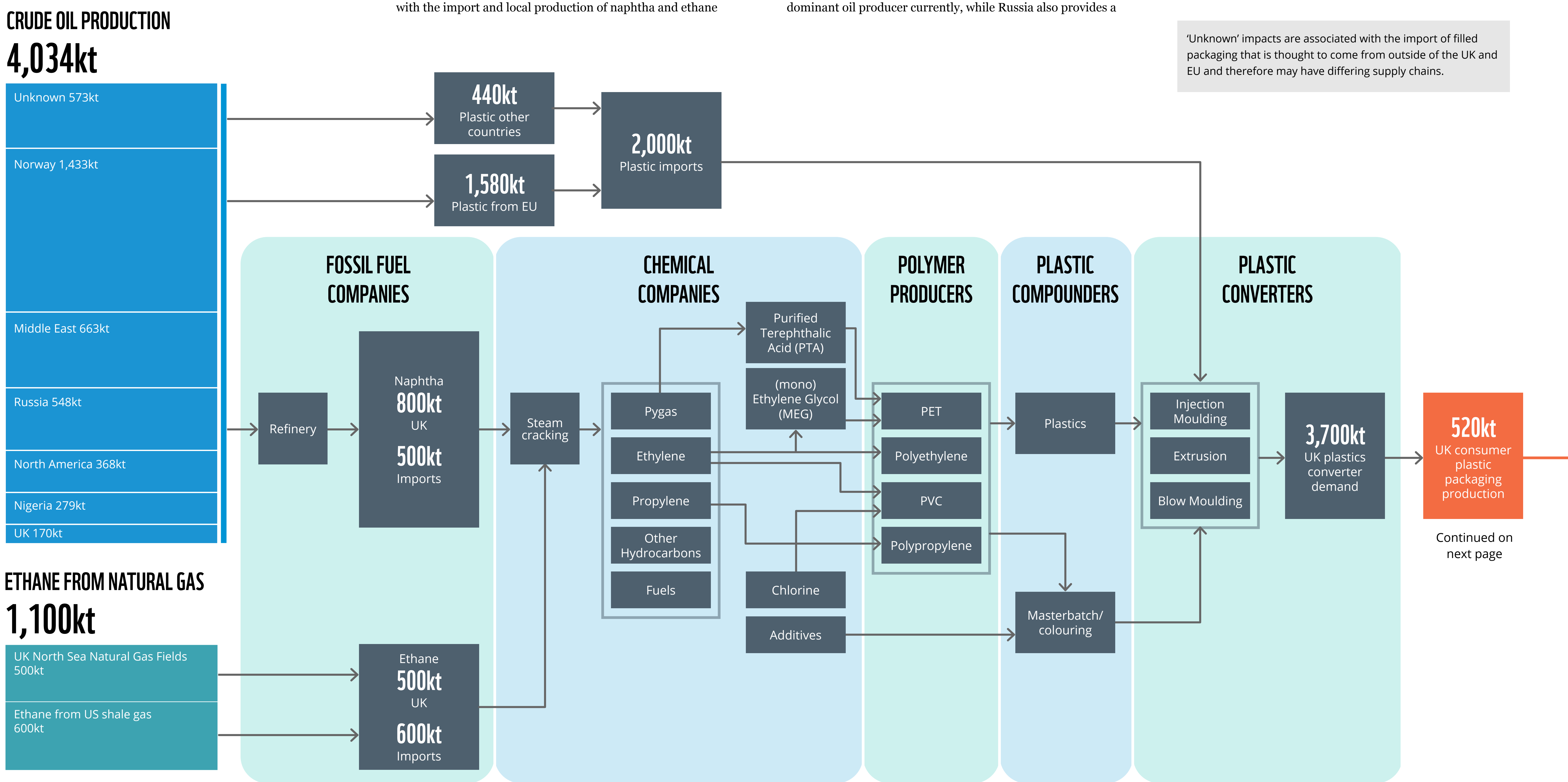
UK PLASTIC VALUE CHAIN

The following analysis focuses on three polymers – PET, PP and PE – as these make up 94% of packaging polymers in the UK. Due to the extremely complex nature of the plastics value chain, it was not possible to fully track the trade flows in the same way that could be achieved with other materials. This is because the raw materials (oil and gas) are used for many other applications and come from all over the world.

There are also several different pathways to producing the same polymer although polyolefins (PE and PP) are most often produced by a process called steam cracking. This uses energy to produce monomers (ethylene and propylene) from hydrocarbons, though other hydrocarbons are also produced for use in other chemical products. In the UK, this starts with the import and local production of naphtha and ethane which are cracked in one of three UK steam crackers operated by Ineos, ExxonMobil/Shell and Sabic. Where oil-derived naphtha is the dominant precursor in the rest of Europe, ethane is increasingly being used in the UK due to the availability of low-cost shale gas from the US. Compressed ethane can be shipped economically in tankers to the coastal locations of the UK crackers; in contrast, moving compressed gas to European producers' inland facilities is more costly. Ethane is now responsible for two-thirds of the UK's ethylene.

Although exact material flows could not be identified, the key precursor to polyolefins in Europe – naphtha – comes from crude oil produced in many countries. Norway is the dominant oil producer currently, while Russia also provides a significant amount along with Middle Eastern countries and, to a lesser extent, the US. Asia appears to play a relatively insignificant role in the raw materials for plastics production in the UK and Europe. While data exists on the import and exports of oil and gas products and UK cracker capacities are known, what takes place between these first steps and UK plastics convertors is relatively opaque as the value chain is not linear in the same way as for other materials. We also assume that oil and gas used for polymers reflects the market in general, with only around 10% of crude oil in the UK used for plastics, with the remainder used primarily for combustion in transport and heating.

'Unknown' impacts are associated with the import of filled packaging that is thought to come from outside of the UK and EU and therefore may have differing supply chains.



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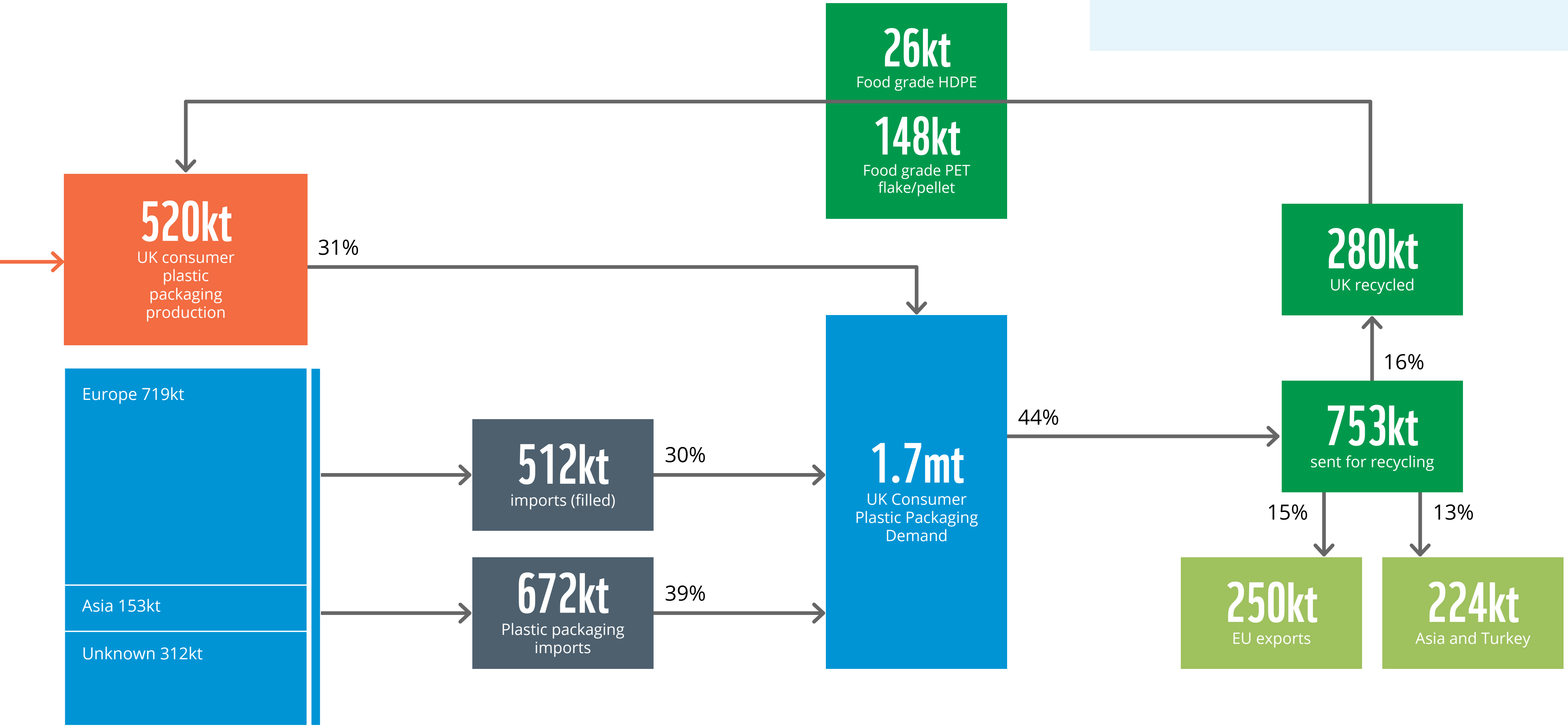
PLASTICS PACKAGING FLOWS INTO THE UK

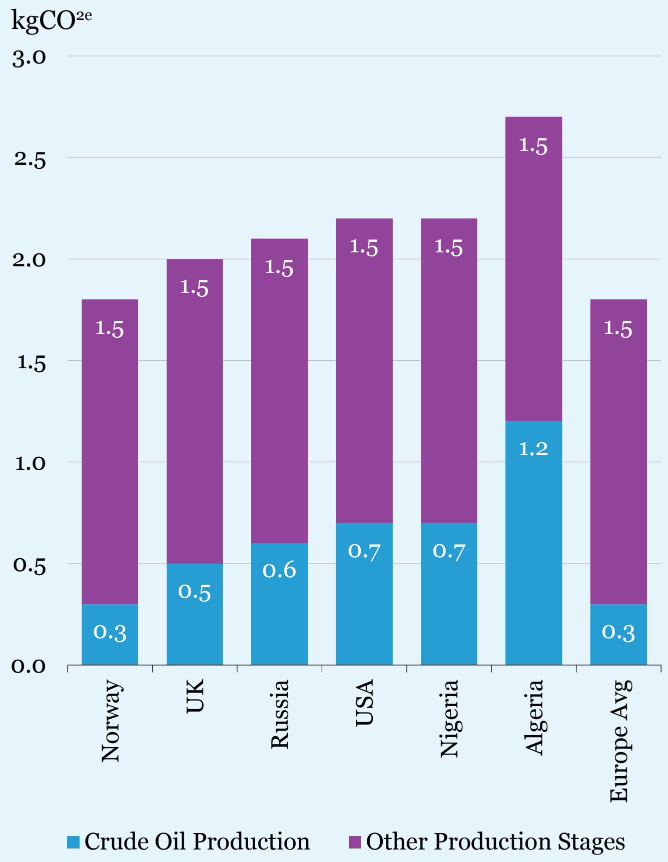
Given the complexity of the value chain, it was not possible to define a full and complete mass flow, but we can see that 69% of plastic packaging is imported, with 64% of this coming from Europe and around 11% from Asia. There is trade data specifically for the imports of plastic packaging although the polymer type is unspecified. As for other materials, the packaging origin of filled imports is also unknown.

For recycling, HDPE milk bottles have been collected for closed-loop recycling since 2009 with a reported 26,000 tonnes being used in new bottles.[14] PET bottles have a reported recycling rate of 59% (270kt), although the UK has reprocessing capacity for just over half of this (148kt).[15] These polymers are likely to account for the majority of closed-loop recycling, but only account for around one-third of reported recycling. Other items made of flexible films are not likely to be recycled in any significant quantities at present due to challenges with collecting, sorting and the lack of demand from reprocessors who focus on the abundantly available rigid plastic packaging that is more economical to recycle. Two-thirds of plastic collected for recycling is exported, which means only 16% of plastic packaging placed on the market in the UK is recycled in the UK (though this may be considerably less once processing losses are accounted for).

Around half of the exported plastic is destined for outside the EU, predominantly Turkey, the UK's third biggest waste export market. Several examples of Turkey mismanaging plastic waste imports came to light during 2020, raising questions over whether exports to this country (and others outside the EU) are actually being recycled.[16] For this reason, exports of plastic outside the UK and EU are considered too unreliable to be counted in this analysis. This leads to an overall recycling rate of 31% (16% in the UK and 15% in the EU).



Environmental Impacts Comparison by Production Stage



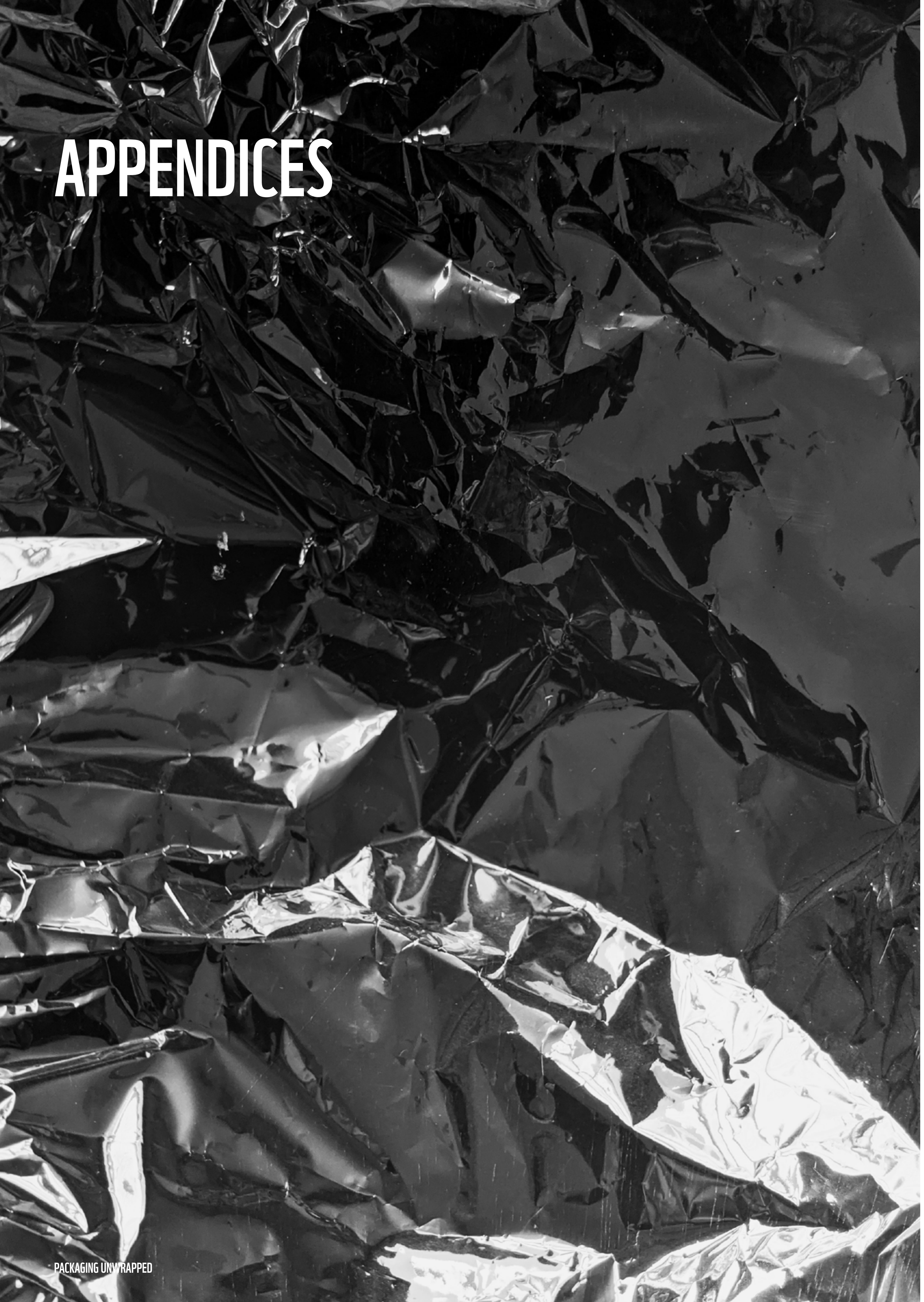
The main obstacle to determining the spatial distribution of environmental impacts from plastics production is the dispersed nature of the industry, which makes it challenging to track trade flows. With the data available it is not possible to assign environmental impacts of raw material extraction (oil and gas) to individual countries, particularly since plastic feedstocks produce a range of other outputs.

The availability of disaggregated inventory data is also a key obstacle. The dataset that is commonly used is based on eco-profiles from Plastics Europe.[17] This is comprehensive and provides a European plastics industry average for most of the common polymers. However, it does not separate out the individual processes (e.g. oil extraction, refining, cracking, polymerisation) as this information often comes from confidential sources. This means it is not possible to determine whether supply chain changes will affect the results.

An example of this is the shift in UK raw material supply from European oil-based naphtha to US shale gas ethane for PE and PP production. The impacts of this particular change are unclear for the UK. One 2013 study from the US suggests there is a slight environmental benefit to producing ethylene from ethane rather than naphtha,[18] although shipping it across the Atlantic may negate any benefit (compared with North Sea gas). However, uncertainty exists around methane emissions in the life cycle of natural gas production from shale in the US. These emissions are thought to vary considerably between extraction sites and are likely to be underestimated in official records; the difference in emissions between sites in the US could be up to four times.[19] The results of this type of research have yet to be incorporated into inventories that are used to calculate the environmental impacts of plastics production.

For naphtha-based monomers, it was possible to track down some of the key oil producing countries responsible for the raw material extraction and there is some evidence to suggest that, at least for GHGs, there is significant variation. For example, the GHG emissions associated with extraction in Algeria are around four times those of Norway. Later production stages account for a much greater proportion of the overall impact, but the difference between these two countries' oil extraction activities results in a 50% difference for the final HDPE polymer. Figures typically used in life-cycle assessments from Plastics Europe rely on older oil extraction data (2010) and apply averages based on the oil supply at that time. However, more recent studies show GHG emissions from oil extraction are likely to be underestimated, and also highly variable depending upon location.[20] Equally, these emissions are thought to increase over time as an oil field ages, which suggests that data from a single point in time cannot be relied upon and continuous monitoring and reporting should be the norm.[21]

Until robust and reliable reporting of emissions from extraction is required by all governments, this is likely to continue. The current situation is that the data surrounding the environmental impacts of plastics is almost impossible to verify and attempts to do so point towards a likely underestimation of impacts.



APPENDICES

Environmental assessment methodology

Environmental assessments or more regimented versions such as life cycle assessment (LCA) require a vast amount of data to calculate impacts. This begins with activity data, which is used to create an inventory. The inventory contains all the emissions to air, water and land as well as resource use that go into a product or process. The primary source for data in this study is the Ecoinvent database[22] which is generally transparent but does not always have the latest available data. This is supplemented by specific industry data where available.[23] For each material, a summary of the data limitations is outlined in the relevant sections.

The next stage is to take the emissions inventory and apply factors which convert the emissions into impacts – the life-cycle impact assessment. The methodology used for this is ReCiPe.[24] This was chosen due to its common usage in LCA, completeness, and the option to use 'endpoints'. For example, GHG emissions cause climate change (midpoint), the effects of which are linked to disease and malnutrition which can cause damage to human health (endpoint). The effects of climate change also cause damage to ecosystems as another endpoint. Simultaneously the effects also damage terrestrial and freshwater species, with an endpoint of damage to ecosystems. For human health, the endpoint unit is DALY – disability-adjusted life years – in the population exposed, which is a measure of the life years lost due to ill-health, disability or early death. For ecosystem quality, the endpoint unit is PDF – potentially disappeared fraction of species – at the global scale as a measure of species that may be lost. ReCiPe also includes a third endpoint – damage to resource availability – which converts use of mineral and fossil resources into an increased cost to extract. As this is an economic measure, this endpoint is excluded from the study.

The second element to this methodology is to bring in a method of spatially differentiating impacts on biodiversity from land-based activities such as mining or forestry. ReCiPe does not have this functionality as it does not differentiate the level of impact by location (i.e. $1m^2$ of land use is given the same impact regardless of geographical location). This is not a weakness of the ReCiPe methodology specifically, as LCA in general rarely considers how a product or process might vary in its spatial impacts along the value chain.

We have used LC-IMPACT[25] to modify the results of ReCiPe to provide this extra dimension. This is applied specifically to material extraction activities as the impacts are primarily felt at the local level because of land-use changes. Other activities further along the value chains tend to be more focused around the impacts of energy consumption, where the cumulative effects are felt locally as well as the resulting contribution to global impacts such as climate change.

LC-IMPACT determines species loss based on spatially differentiated global maps of species in various taxonomic groups, including vascular plants, fish, birds, mammals, amphibians and reptiles. This is disaggregated at the country level. However, impacts in nature do not necessarily follow country boundaries that may consist of many varied ecosystems that are sensitive to certain activities. The estimated impacts are still based upon modelling using weighted averages, so the results should be used as a signpost for more research rather than a report of the absolute impacts. Five midpoint impact categories for ecosystem impacts have spatially differentiated information that allows this method to be used.

To join the two methods together, we assume that ReCiPe uses impact categories that are representative of the global average. The impact categories are then modified based on their deviation from the average, which might represent an increase or decrease in impact for certain categories e.g. for land occupation in Jamaica the impact is 21 times greater than the global average, which is the factor used to modify the results from ReCiPe.

With regard to the system boundary, the main focus of this study is on the impacts associated with the virgin demand rather than an assessment of the full life cycle of the materials. Material that is sent for recycling is offset against the requirement for virgin equivalents (where the recycling is expected to displace the same type and quality of material); however, this study does not account for losses in the recycling process or the environmental impacts of the recycling process itself. Nor does it cover the well-documented impacts of plastic pollution or mismanagement of other material wastes. It should therefore be considered as a first step in providing an indication of the environmental impacts and which countries might be contributing, rather than a full and comprehensive cradle-to-grave LCA of the whole packaging value chain.

Trade and material flow data sources

As well as the Comtrade database[26] for material flows, the National Packaging Waste Database (NPWD) is a key source of information to determine the amounts of packaging placed on the UK market and whether it is imported.[27] The NPWD contains data on placed on market tonnages and material reported as recycled. However, the NPDW only collects data from packaging producers that are 'obligated' under the UK packaging Extended Producer Responsibility scheme, which covers those handling more than 50 tonnes of packaging per year and with an annual turnover greater than £2 million. To estimate non-obligated sources, WRAP and Valpak produce annual material flow reports which use the NPWD data as a basis for further analysis into the make-up of the packaging market for each material.[28] These reports, and the assumptions they contain, are also used in the present study where appropriate.

The reporting by companies that forms the NPWD dataset also only requires companies to report the mass of the packaging for the predominant material. This is problematic for composite packaging that contains several dissimilar materials that cannot be economically separated. Material measurement and reporting issues are discussed further in the relevant material sections; however, the main packaging materials that are likely to be 'lost' under this system are polymers and aluminium in liquid beverage cartons, polymer coatings in steel and aluminium cans, and the aluminium layer in flexible plastic foil composites.

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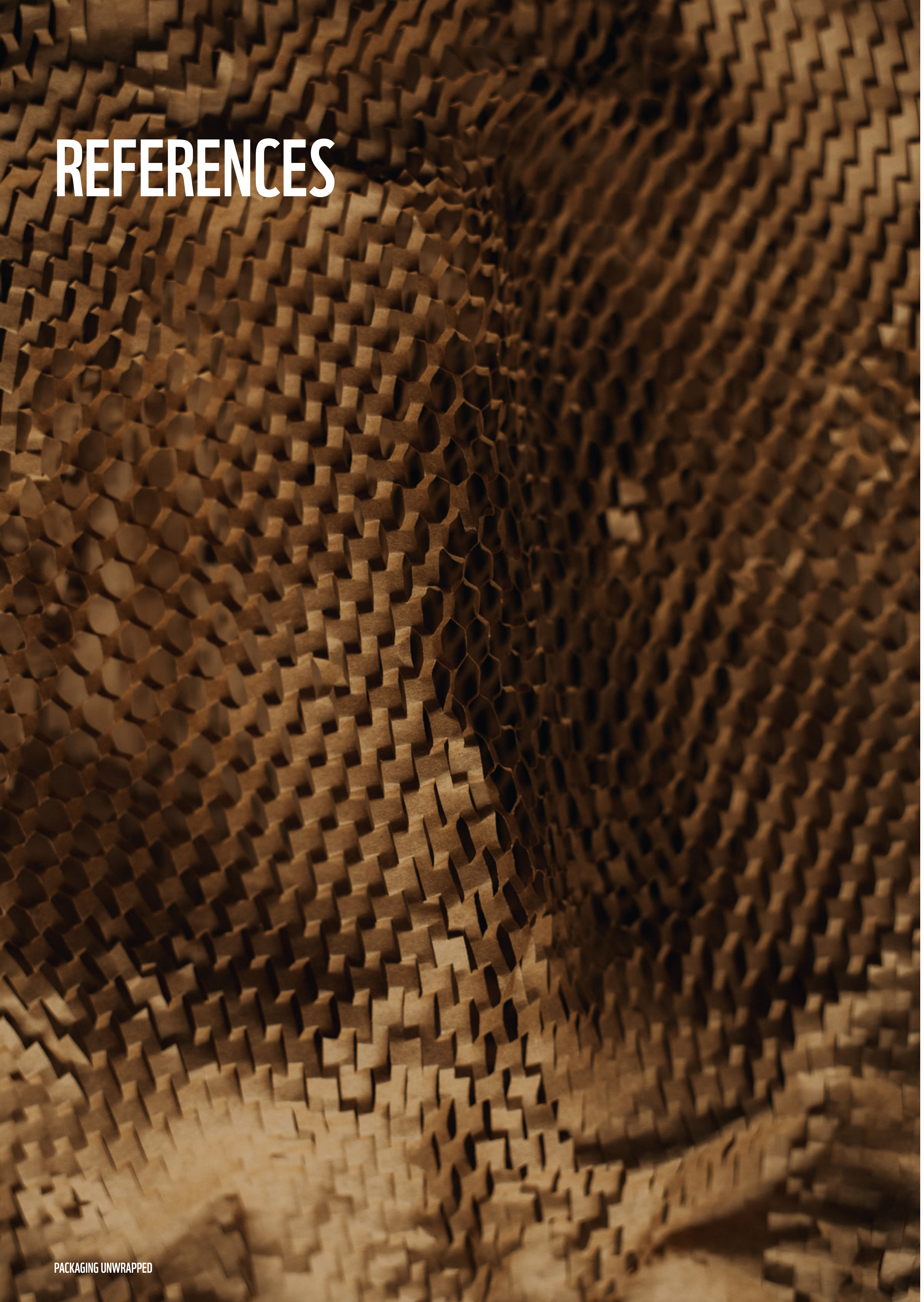

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