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# Updated life-cycle assessment of graphic and tissue paper

## spotlight report

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ifeu, Heidelberg

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**Abstract: Updated life-cycle assessment of graphic and tissue paper**

The last life-cycle assessment of the German Environment Agency for graphic papers, in which the environmental impacts of virgin papers and recycled papers were comprehensively examined, dates from the year 2000 (Tiedemann et al. 2000). A key finding of this study was that "it is much more environmentally friendly to produce graphic papers from recycled fibres than to use virgin fibres from wood as a raw material".

The award criteria of the Blauer Engel (Blue Angel) eco-label for paper products are also based on the results of this study and demand the highest possible use of recycled paper, preferably from post-consumer waste, as raw material for paper production.

The present study is an update of this LCA. It has been extended to include the consideration of tissue papers and a discussion on biodiversity, land use change and carbon capture in forests. A special focus is also placed on paper recycling in Germany.

The updated results largely support the previous UBA recommendations and the requirements of the Blue Angel eco-label for the promotion of recycled paper. It is much more environmentally friendly to produce graphic paper from recycled fibres than to use virgin fibres from wood as raw material.

**Kurzbeschreibung: Aktualisierte Ökobilanz von grafischen und Hygienepapieren**

Die letzte Ökobilanz des Umweltbundesamtes für grafische Papiere, in der die Umweltwirkungen von Primär- und Recyclingpapieren umfassend untersucht wurden, stammt aus dem Jahr 2000 (Tiedemann et al. 2000). Ein zentrales Ergebnis dieser Studie war, dass "die Herstellung von grafischen Papieren aus Recyclingfasern wesentlich umweltfreundlicher ist als die Verwendung von Frischfasern aus Holz als Rohstoff".

Die Vergabekriterien des Umweltzeichens Blauer Engel für Papierprodukte basieren ebenfalls auf den Ergebnissen dieser Studie und fordern die höchstmögliche Verwendung von Recyclingpapier, vorzugsweise aus Post-Consumer-Abfällen, als Rohstoff für die Papierherstellung.

Die vorliegende Studie stellt eine Aktualisierung dieser Ökobilanz dar. Dabei wurde sie um die Betrachtung von Hygienepapieren, und eine Diskussion über Biodiversität, Landnutzungswandel und Kohlenstoffspeicherung ergänzt. Besonderer Fokus liegt zudem auf dem Papierrecycling in Deutschland.

Die aktualisierten Ergebnisse stützen weitgehend die bisherigen Empfehlungen des UBA und die Anforderungen des Ökolabels Blauer Engel zur Förderung von Recyclingpapier. Es ist wesentlich umweltfreundlicher, grafisches Papier aus recycelten Fasern herzustellen, als neue Fasern aus Holz als Rohstoff zu verwenden.

# Preface

This present spotlight report provides the core facts and main findings of the LCA study and additionally addresses land use criteria that are difficult to quantify, such as biodiversity, land use change and carbon storage in forests. It also includes a section providing a better understanding on how the paper cycle related to office and tissue paper can be strengthened and on how Eco-lables can contribute to this objective.

In addition to this spotlight report, a background report (UBA 2022) is also available for download from the website of the German Environment Agency. It includes a much more comprehensive and detailed description of assumptions and data, and also addresses several additional aspects not covered in the spotlight report. These are for example the consideration of different fibre compositions including the use of grass fibres or the assessment of a final product on the consumer level.

The study was commissioned by the German Environment Agency UBA on the 21st of June 2017. Main contractor is Institut für Energie- und Umweltforschung Heidelberg gGmbH (Institute for Energy and Environmental Research, Heidelberg) (ifeu), sub-contractor is Forum Ökologie & Papier (Forum Ecology & Paper) (föp) for market research.

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## List of abbreviations

| | |
|---|---|
| **ADMT** | Air-dried metric ton |
| **AGRAPA** | Arbeitsgemeinschaft Graphische Papiere |
| **AOX** | Adsorbable organically bound halogens |
| **BREF** | Best available techniques reference document |
| **CED** | Cumulated energy demand |
| **CHP** | Combined heat and power plant |
| **$CO_2$** | Carbon dioxide |
| **COD** | Chemical oxygen demand |
| **DIP** | Deinked pulp |
| **ECF** | Elementary chlorine-free |
| **EPD** | Environmental Product Declaration |
| **FSC** | Forest Stewardship Council |
| **GLOBIOM** | Global Biosphere Management Model |
| **ifeu** | Institut für Energie- und Umweltforschung Heidelberg GmbH (Institute for Energy and Environmental Research, Heidelberg) |
| **ILCD** | Guideline for the creation of an ecological footprint of paper (intermediate) products based on the proposed EU methodology for Life Cycle Assessment |
| **IPR** | Initiative Pro Recyclingpapier (Initiative for Sustainable Use of Paper) |
| **LCA** | Life Cycle Assessment |
| **LWC** | Lightweight coated (paper) |
| **NMIR** | Maximum incremental reactivity taking into account NOx sensitivity |
| **$NO_x$** | Nitrogen oxide |
| **MIR** | Maximum incremental reactivity |
| **MSWI** | Municipal Solid Waste Incineration |
| **PEFC** | Programme for the Endorsement of Forest Certification Schemes |
| **PEFCR** | Product Environmental Footprint Category Rules |
| **PfR** | Paper for recycling |
| **PM 10** | Particulate matter with particle diameter smaller than 10 µm |
| **PCR** | Product Category Rules |
| **PEF** | Product Environmental Footprint |
| **$PO_4$** | Phosphate |
| **POCP** | Photochemical Ozone Creation Potential |
| **SC** | Super calandered (paper) |

| | |
|---|---|
| **$SO_2$** | Sulphur dioxide |
| **TCF** | Total chlorine-free |
| **UBA** | Umweltbundesamt (German Environment Agency), Dessau |
| **VDP** | Verband Deutscher Papierfabriken |

## Units and dimensions used

| | |
|---|---|
| **µm** | micrometre, $10^{-6}$ metre |
| **L** | litre |
| **$m^2$** | square metre |
| **$m^3$** | cubic metre, 1.000 litres |
| **mg** | milligram |
| **g** | gram |
| **kg** | kilogram, 1.000 grams |
| **t** | tonne, 1.000 kilograms |
| **kJ** | kilojoule, 1.000 joules |
| **kt** | kilotonne, 1.000 tonnes |
| **MJ** | megajoule, 1.000.000 kilojoules |
| **W** | watt |
| **MWh** | megawatt hours, 1.000 kilowatt hours |
| **a** | year |

**Note on decimal separator:**

The symbol used as the decimal separator throughout this document is a comma. This is in line with the recommendations of (ISO 80000-1 2013) for international documents.

# 1 Goal and scope

## 1.1 Background and Objectives

In the year 2000 the German Environment Agency (UBA) published a comprehensive life-cycle assessment of graphic papers (Tiedemann et al. 2000), which for the years thereafter became a reference study for setting up guidelines for paper procurement in public entities as well as private companies.

The study examined the German market for graphic papers including imported paper and fibres. It was based on an extensive gathering of process data for all major grades of graphical paper, including data for paper and pulp mills in the Nordic countries. The LCA model comprised the complete graphic paper cycle with all fibre and paper flows contained and the total consumption of graphic papers in Germany. A key finding of this study was that "it is much more environmentally friendly to produce graphic papers from recycled fibres than to use virgin fibres from wood as a raw material". The current award criteria of the Blauer Engel (Blue Angel) eco-label for paper products are also based on the results of this study and demand the highest possible use of recycled paper, preferably from post-consumer waste, as raw material for paper production.

A much more confined study limited to office paper was conducted in 2008 on behalf of UBA (Detzel et al. 2008) with the purpose to inform UBA on the impact of at the time ongoing improvement measures in the paper industry – especially a shift towards a higher share in renewable energy use combined with increased energy efficiency - on the environmental profile of office paper. The study results were temporarily made available on the UBA website, but not separately published in form of a report.

Maintaining the 10 years updating frequency, UBA in 2017 commissioned this present study in order to inform paper related decision-making based on the current situation of office and tissue paper produced for consumption in Germany and its potential implications for future revisions of paper-related eco-labels. The objectives set out by UBA not only comprised an assessment of the (comparative) environmental performance of virgin and recycled papers by means of LCA but also requested a consideration of criteria that are difficult to quantify, such as biodiversity, land use change and $CO_2$ storage in forests as well as a description of the framework conditions for further improvement of the paper cycle. The study is divided into two reports, this spotlight report and a background report that considers additional perspectives (see 1.2.1) and delivers more detailed information on certain aspects like data and methodology used.

## 1.2 Goal and scope of the life-cycle assessment

### 1.2.1 System boundaries

In this present study, three different perspectives on paper and paper products respectively were considered. In this spotlight report, only the first is included. The other two approaches are included in the background report (UBA 2022):

1. Paper at the paper mill outlet (intermediate paper product)
   This is modelled in form of a cradle-to-gate system boundary (Figure 1)
2. Ready-for-use paper products (final paper product)
   This is modelled in form of a cradle-to-grave system boundary (Figure 1)

3. Paper in a multiple recycling chain
   For more information on this perspective please consult the background report (UBA 2022).

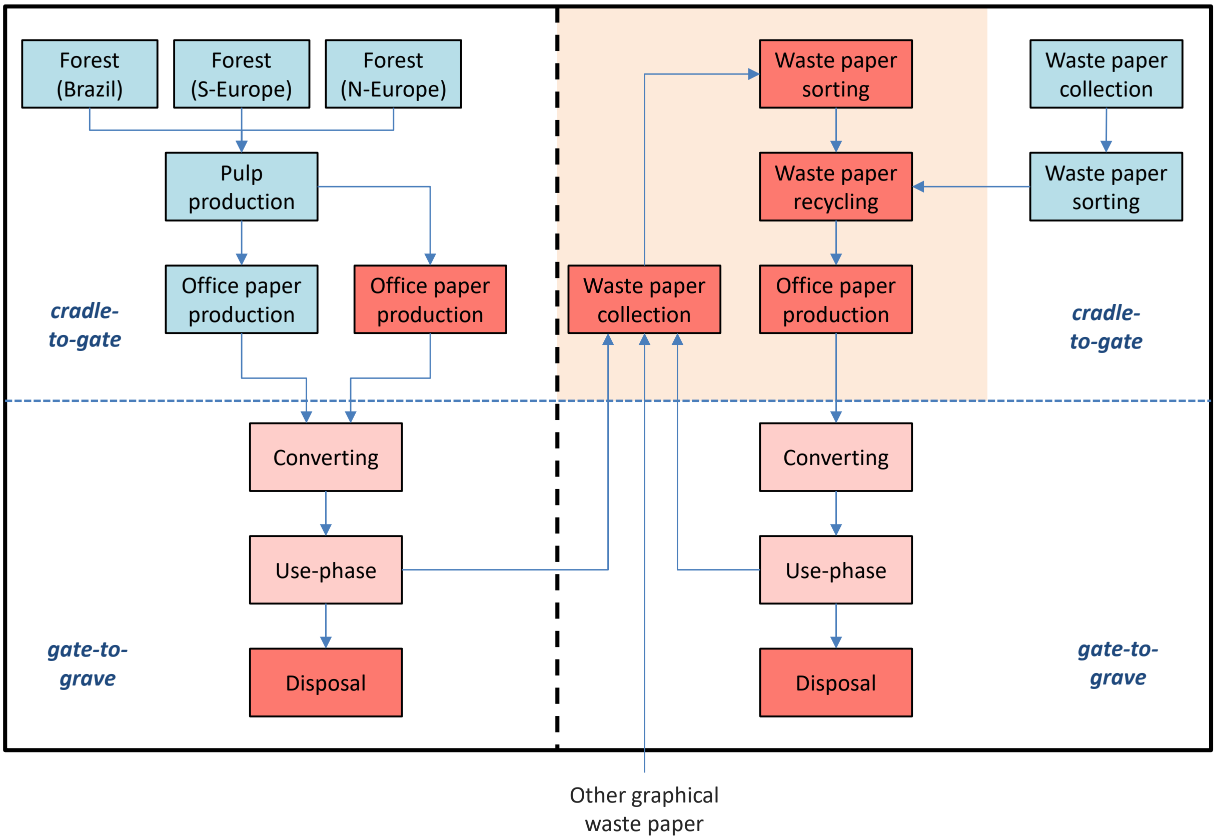
Each perspective requires a specific setting of the system boundaries and may also involve decisions on allocation. Figure 1 below shall help to illustrate this for the cradle-to-gate and the cradle-to-grave approach. As can be seen, the cradle-to-grave perspective in principle only differs from the cradle-to-gate perspective in that it adds further life cycle steps – including conversion to a ready-for-use paper product. Both perspectives can be applied to virgin as well as recycled paper and paper products, which both – and this is important to bear in mind – on the market must deliver the same functionality in terms of printability, tear strength etc.

While Figure 1 on the one hand shows that virgin and recycled paper are part of an interconnected material flow system, in order to compare one with the other - which is one of the main objectives of this present study - the related systems need to be examined separately as indicated by the vertical dotted line in figure 1. As both systems are interconnected such a separation requires a decision whether environmental loads are shared between both systems, and if yes to which ratio, or not. This burden sharing decision is called "allocation" and the ratio is referred to as the "allocation factor". If no allocation is carried out, this is called "cut-off" approach, in reference to the fact that the assessment of the respective products only comprises the processes within the depicted system boundaries without accounting for activities in proceeding or follow-up systems.

For a direct comparison of virgin paper and recycled paper only the gradle-to-gate boundaries are relevant because the impacts caused by the conversion to final products, the use phase and disposal can be considered the same. In that sense, the virgin paper route and the recycled paper route describe two ways to produce the same product function but with different raw materials. Furthermore, for a plain understanding of the differences, it does not make sense to share environmental loads between both routes. Therefore, in this present study the cut-off approach is applied for the LCA comparison of virgin and recycled papers and also forms the basis for the LCA scenarios and results presented in this spotlight report. For transparency reasons, it is the objective of this study to present the information in a way that makes the comparison of different processes possible. For the evaluation of the environmental footprint of a product, allocation of environmental burden of the pre-life of the product can be conducted when appropriate.

It is important to highlight that such a separation is only valid as long as the required fibre quality within the overarching paper cycle is maintained by a sufficient amount of virgin fibres continuously refreshing the fibre pool. Therefore, and in acknowledgement that an allocation of environmental loads between virgin and recycled paper systems also is often applied in paper-related LCA studies, a 50:50 allocation approach has been applied in the cradle-to-grave assessment of an exercise-book the results of which are documented in the background report (UBA 2022). In addition, sensitivity scenarios are applied taking into consideration the circular footprint formula as an allocation alternative as well as different approaches regarding the assessment of biogenic carbon uptake and emissions, also documented in the background report (UBA 2022).

**Figure 1: System boundaries for the current study**




Blue boxes: Processes that are located outside Germany
Red boxes: Processes that are located within Germany
Cradle-to-gate: Basic model of the system boundaries, which allows a direct comparison of the centrally different steps in the production process.
Gate-to-grave: Exemplary inclusion of processing into consumer-related products (e.g. exercise books) and disposal processes to determine the environmental profiles of the entire life cycle and the related hotspots.
Source: Own depiction 2021, ifeu

The production of papers from primary fibres includes the processes:

- Forestry wood supply
- Fibre preparation
- Paper production
- Paper transport

The production of papers from recycled fibres includes the processes:

- Waste paper sorting and delivery to waste paper processing
- Recovered paper preparation, DIP production
- Paper production
- Paper transport

### 1.2.2 Functional unit

The functional units for the cradle-to-gate results presented in this spotlight report are as follows.

- The production of 1 tonne of office paper 80 g/m² (as representative for writing paper) and its provision for transport at the gates of the production site
- The production of 1 tonne of tissue paper 16 g/m² (corresponds to one layer of toilet paper) and its provision for transport at the gates of the production site

  To achieve the same end product quality for other tissue products it may be necessary to increase the grammage of recycling products, or to use strength additives or fresh fiber, this can be seen especially in towel products.

### 1.2.3 Environmental impact categories and inventory indicators

The selection of environmental impact categories and the methods used for environmental assessment in the current project are based on the UBA guidelines on life cycle assessment, which are set out in UBA texts 23/95 (UBA 1995) and 92/99 (UBA 1999). These methodological guidelines were under revision by UBA at the time of this project. Unfortunately, a new set of methods has not been published until the final stage of this project and therefore could not be applied for this study.

The following environmental impact and inventory categories are covered in this study (*not assessed inventory categories in italics*):

- Climate Change
- Acidification
- Terrestrial Eutrophication
- Aquatic Eutrophication
- *Process water (freshwater) demand*
- *Adsorbable Organic Halogenated Compounds (AOX)*
- *Cumulative energy demand (CED non-renewable)*
- *Cumulative energy demand (CED) renewable*
- *Cumulative energy demand (CED) without feedstock energy*
- *Cumulative energy demand (CED total)*
- Photo-oxidant formation
- Particulate matter (PM 2.5)

- Ozone depletion

In section 3 of this report, biodiversity and land use change as well as $CO_2$ storage in forests are discussed on a mainly qualitative level. In addition, it also includes the application of an assessment methodology for biodiversity.

Note on the assessment of climate change in regard to the treatment of biogenic carbon:

In recent years, the calculation of carbon impacts of forest biomass is questioned, especially regarding burning the wood for energy generation. This discussion covers several carbon-related aspects: carbon contained in wood with emphasis on the timing of biomass growth versus the timing of emissions, carbon from land use change, and reductions in the carbon storage capacity of forests. There have been developed and exemplified dynamic approaches that consider temporary effects of biogenic carbon dioxide emissions on climate change until being captured again or carbon budgets models that calculate carbon fluxes under changing forest management systems (Tellnes et al. 2017; Hoxha et al. 2020, Matthews et al. 2014). This valuable research shows the need for a critical consideration of the classification of biomass by the European Union Emissions Trading Scheme, which currently gives preferential treatment to greenhouse gas emissions associated with biomass combustion. Even though dynamic modeling of biogenic carbon fluxes in LCA is desirable, current calculation models are associated with high variability and different approaches provide different results. Moreover, there is currently no scientific consensus on which method is the most suitable for use in LCAs (Tellnes et al. 2017; Hoxha et al. 2020; UBA 2016). The study of (Matthews et al. 2014) carried out for the European Commission concludes that due to the variability of biogenic sources in terms of associated GHG emissions, a qualitative assessment using a decision tree is best suited to identify risks related to GHG emissions. Since the location of forests claimed for paper production is uncertain (see section 3), the question also arises within this study as to exactly what potential forest carbon losses paper production would be responsible for. Therefore, risk of land use change and principles of forest management that counteract a positive carbon balance are discussed qualitatively in section 3. Quantifying the carbon dynamics associated with paper production or uptake using currently developed models to calculate the forest dynamics of the forest area associated with paper production would more appropriately be the subject of a separate research project.

Therefore, this study follows the rules of currently existing LCA methods. Following the approach of ILCD 2010, PAS 2050 and ISO-14067, biogenic GHG emissions and removals within the 100-year period are considered as if they were released or removed at the beginning of the assessment period.

### 1.2.4 Market research and cluster development

In order to be able to make LCA comparisons of papers made from virgin fibres and papers based on recycled fibres, their origin, raw material procurement and manufacturing methods must be known. To this end, the contractors (for the most part FÖP) have surveyed paper wholesalers and retailers to determine as completely as possible the amount of copy and tissue paper used in Germany and its producers. In a second step of the research, the paper manufacturers were contacted to supply the data on the respective production sites and methods, as well as on the supplier countries or regions of the virgin and recycled fibres used. Only a few of the contacted producers supplied any market data, so that it was not possible to assess the overall market based on the collected data.

For this reason, data research based on publicly available data sources has been carried out in order to define suitable paper product clusters that will be examined by means of LCA scenarios.

Public data sources used to derive mass flows on the market that define paper product clusters to be examined are the following:

- Report on recycled paper (IPR 2015)
- Public statistics (StBA 2019)
- Environmental reports of producers of fibrous material and paper
- Annual report of German Pulp and Paper Association (Moldenhauer et al. 2018)
- Primary data provided by a German recycling paper producer
- Reference document on "The best available techniques in the pulp and paper industry" (EU COM, PPP BREF 2015)

#### 1.2.4.1 Market analysis

Market results office papers:

Annual consumption of office papers in Germany is around 600.000 t/a (IPR 2016). According to (IPR 2015), the market share of 100% recycled office papers in Germany is 14 %, which corresponds to 84.000 t/a.

In a next step, A4 paper imports to Germany were analysed based on import statistics (StBa 2019) for the year 2017. As imports from non-European countries are below 5 % of total office paper imports, only European imports are considered for the further clustering process. Relevant imports are summarised in the following Table 1. Individual countries of origin as listed in the import statistics are then classified into a production type, based on public information available from office paper production companies / site-specific public information (UPM 2020, Stora Enso 2020, Leipa 2020). Production types are distinguished between integrated and non-integrated production. These are defined by (EU COM PPP BREF 2015) as:

- integrated production
  Both pulp and paper/board are produced at the same site. The pulp is normally not dried before paper/board manufacture.
- non-integrated production
  Either (a) production of market pulp (for sale) in mills that do not operate paper machines, or (b) production of paper/board using only pulp produced in other plants (market pulp).

**Table 1: Classification of imported office papers into paper production types**

| Country of origin | Production type | Imported mass (2017) kt/year* | Important production sites |
|---|---|---|---|
| Austria | virgin, non-integrated | 100 | Mondi (Theresienthal) |
| France | virgin, non-integrated and virgin, integrated | 48.5<br>48.5 | International Paper (Saillat), Clairefontaine |

| Country of origin | Production type | Imported mass (2017) kt/year* | Important production sites |
|---|---|---|---|
| Slovakia | virgin, integrated | 80 | Mondi Rezemberok |
| Poland | virgin, non-integrated | 15 | International Paper (Kwidzyn) |
| Portugal | virgin, non-integrated and virgin, integrated | 34.5<br>34.5 | Navigator |
| Sweden | virgin, integrated | 56 | Stora Enso (Nymölla) |
| Finland | virgin, integrated | 40 | UPM (Kymi), Stora Enso (Kemi) |
| *Total import* | *virgin, non-integrated and virgin, integrated* | *198*<br>*+259*<br>*=457* | |

*Source of import numbers: (StBA 2019), reference year 2017

The split between integrated and non-integrated for countries France and Portugal is assumed to be 50/50.

Besides the origin of imported papers, also information on pulp origin especially for non-integrated paper production is relevant in order to derive representative market clusters. As no primary information could be collected from office paper companies in course of the research project, pulp import statistics based on (Moldenhauer et al. 2018) are used instead as data source for pulp origin, differentiated into long and short fibres. The following Table 2 summarizes the most important pulp imports as considered for the non-integrated office paper production.

**Table 2: Origin of market pulp (for paper from non-integrated production)**

| Fibre type | Country of origin | Imported mass (2017) kt/year* |
|---|---|---|
| Short fibre, hardwood | Brazil | 1.140 |
| | Uruguay | 165 |
| | Chile | 199 |
| | Portugal | 380 |
| | Spain | 213 |
| *Total hardwood pulp* | | *2.097* |
| Long fibre, softwood | Sweden | 510 |
| | Finland | 310 |
| | Canada | 35 |
| | United States | 95 |
| *Total softwood pulp* | | *950* |

*Source of import numbers: (Moldenhauer et al. 2018)

For the cluster definition, a distribution of fibre origin based on the above presented data is derived as 72 % from Latin America and 28 % from Southwest Europe for short fibres and as 87 % from Northern Europe 13 % from North America for long fibres, respectively. This covers >88 % of short fibre imports and >98 % of long fibre imports into Germany in 2017. The typical share of different virgin fibres for both integrated as well as non-integrated office papers are 85 % short fibres and 15 % long fibres.

**Derived clusters office papers:**

The following Table 3 summarises the derived office paper clusters and their market shares for the German office paper market, based on raw data shown in the previous tables. The difference between imported office papers, recycled office papers produced in Germany and the German office paper market of 600.000 tonnes is assumed to come from non-integrated German paper production and thus forms part of the non-integrated paper production in Central Europe.

**Table 3: Cluster Office Paper: Total Consumption Germany 2016: ~600.000 t/a**

| Cluster | Type of paper | Production | Location paper machine | Calculated market volume (kt/a) | Calculated proportion of the german market<br><br>(representative status 97.4 %) |
|---|---|---|---|---|---|
| O1 | virgin | Non-integrated | Central Europe & Southwest Europe | 257 | 43 % |
| O2a | virgin | Integrated | Northern, Central & Southwest Europe | 259 | 43 % |
| O3 | Recycling | Integrated | Central Europe | 84 | 14 % |

Source: (Own depiction 2021, ifeu: IPR, additional sources: VDP: Paper Performance Report 2018 (reference year 2017) / External trade statistics, Federal Statistical Office (reference year 2017)/ primary data collection in the project)

<u>Market results and derived clusters tissue papers:</u>

Annual consumption of tissue papers in Germany (machine production) is around 1.572.000 t/a (Moldenhauer et al. 2018). Primary data on tissue paper production volumes in Central Europe for the German market could be obtained in the course of the present research project from several tissue paper companies (WEPA 2018, Essity 2018, Fripa 2019).

Based on the primary data collected, the classification of tissue paper production types as shown in the following Table 4 is derived.

Table 4: Cluster Tissue Paper: Total Consumption Germany 2017*: 1.592.000 t/a

| Cluster | Type of paper | Production | Location paper machine | Calculated market volume (kt/a) | Calculated market share on the German market<br><br>(representative status 92.4 %) |
|---|---|---|---|---|---|
| T1a | virgin | Non-integrated | Central Europe | 1162 | 73,9 % |
| T2a | Recycled | Non-integrated | Central Europe | 159 | 10,1 % |
| T2b | Recycled | Integrated | Central Europe | 132 | 8,4 % |

*Source of tissue paper market number: (Moldenhauer et al. 2018)

Information regarding pulp origin gathered in course of the present research project from primary data collection is not sufficient to derive an overall pulp origin mix. For this reason, pulp origin for long fibre and short fibre are assumed to be the same as described in the previous paragraphs for office papers, as pulp import statistics do not differentiate by paper product use. So for tissue papers, origin of short fibre is assumed to be 72 % from Latin America and 28 % from Southwest Europe and as 87 % from Northern Europe 13 % from North America for long fibres, respectively. The typical share of different virgin fibres for tissue paper is 80 % short fibres and 20 % long fibres.

### 1.2.5 Life Cycle Inventory data used

One significant component of the project was to collect current unit process data to reflect the production of virgin pulp, as well as data for the production of recycled deinked pulp (DIP) and recycled office and tissue paper production. One approach to collect as much primary data as possible was to ask for the support of the paper industry to provide process datasets. Unfortunately, several meetings with representatives of the industry did not lead to an agreement that process data would be provided for this project. One of the reasons for this were concerns about antitrust rules, which could not be resolved despite an assessment by the UBA's lawyers. Apart from limited market data from some companies and process data for recycled office paper, no primary data could be obtained.

#### 1.2.5.1 Overview on data sources

Without the support of the paper industry regarding process data collection the focus lay on the evaluation of publicly accessible information. This data was supplemented by data on DIP and recycled office paper production obtained from a German recycling paper producer. Overall, the following data sources are used for setting up the LCA models:

- Reference document on "The best available techniques in the pulp and paper industry" (EU COM PPP BREF 2015)
- Ecoinvent life cycle inventor database, Version 3.6 (Ecoinvent 2019)
- Primary data provided by a German recycling paper producer
- Environmental reports of producers of fibrous material and paper

- Internal database of ifeu Heidelberg
- Reference document: „Ökologischer Vergleich von Büropapieren in Abhängigkeit vom Faserrohstoff“ (Gromke, U.; Detzel, A. 2006)

In the following there is a short description how the available data is used for modelling. The modeled clusters are described in Table 3 and Table 4.

#### 1.2.5.2 Non-integrated virgin office paper

The non-integrated production of office paper from virgin fibres, includes the following processes:

- Wood provision from forestry

For Northern pulpwood, the inventory dataset "softwood forestry, pine, Sweden and softwood forestry, spruce, Sweden" taken from (Ecoinvent 2019) are used. For Brazilian eucalyptus wood, the inventory dataset hardwood forestry, *eucalyptus ssp*., planted forest management, Brazil taken from (Ecoinvent 2019) are used. An average of the three Brazilian eucalyptus plantation regions available in the Ecoinvent database (Goiás, Minas Gerais, São Paulo) are used. For Iberian eucalyptus wood, no full inventory dataset is publicly available. For this reason, the Brazilian dataset is used as a proxy dataset with an adaption of harvesting yield. For Central European "hardwood pulpwood, inventory datasets hardwood forestry, oak, Germany" and hardwood forestry, beech, Germany taken from (Ecoinvent 2019) are used. For provision of North American softwood, no full inventory dataset is publicly available. For this reason, the Northern Europe softwood dataset is used as a proxy dataset.

The timber yield or land use of the individual countries and timber species is based on the sources mentioned. It is based on the annual growth of the forests and includes round wood as well as thinning wood that is harvested during the rotation period. As the share of thinning wood for Central European paper production is potentially higher than assumed in the present study, the forest area needed for Central European paper production might be overestimated. The same yield is assumed for different types of forest management (selective logging forestry, clear-cutting or retention forestry).

- Manufacture of market sulphate pulp

The manufacture of sulphate pulp in North America is based on the inventory dataset "sulfate pulp production, from hardwood, bleached" in Canada, Quebec, which is taken from (Ecoinvent 2019). It covers the production of elementary chlorine-free (ECF) bleached sulfate pulp from the kraft process. Underlying data refer to a mix of Canadian mills that pulp both softwood and hardwood. Production is assumed to take place 50 % in Canada and 50 % in the United States.

The manufacture of Latin American sulfate pulp production from eucalyptus is based on the inventory dataset "sulfate pulp production, eucalyptus, bleached, Latin America and the Caribbean", which is taken from (Ecoinvent 2019). It covers the production mix of ECF and total chlorine free (TCF) bleached sulfate pulp from the kraft process in Latin America. As no specific inventory dataset is publicly available for Iberian eucalyptus pulp production, this dataset is also used for Iberian eucalyptus pulp. However, external energy prechains (e.g. electricity) are adapted to Latin America and Iberia.

The manufacture of Northern sulphate pulp is based on "sulfate pulp production, from softwood, bleached, Europe" taken from (Ecoinvent 2019). It covers ECF and TCF kraft pulp, obtained from northern European softwood.

Data sources for prechains of externally procured energy and all relevant preliminary materials and auxiliary chemicals, including their prechains are taken from: (Ecoinvent 2019, Tiedemann et al. 2000, ifeu 2019).

► Refining of pulp

Before entering the paper machines, the dried pulp has to be refined and fibrillated. The energy consumption values used for the milling are based on (Bos 1999) and where required to be adapted to pulp type using experimental values based on (Gehr 2006).

► Office paper production

Paper is made from the supplied pulp in the last process step considered. The inventory dataset "paper production, woodfree, uncoated, at non-integrated mill" taken from (Ecoinvent 2019) is used. Data sources for prechains of externally procured energy and all relevant preliminary materials and auxiliary chemicals, including their prechains are taken from: (Ecoinvent 2019, Tiedemann et al. 2000, ifeu 2019).

#### 1.2.5.3 Integrated virgin office paper

The production of integrated office paper from virgin fibres, includes the following processes:

► Wood provision from forestry

For Northern European integrated production, both Northern hardwood and softwood is required as raw material. For Northern pulpwood, the inventory dataset "softwood forestry, pine, Sweden and softwood forestry, spruce, Sweden" taken from (Ecoinvent 2019) is used. For hardwood forestry in Northern Europe, the inventory dataset "hardwood forestry, birch, Sweden" taken from (Ecoinvent 2019) is applied.

In case of Southern European integrated production, short fibre content is assumed to originate from Iberian Eucalyptus. For Iberian eucalyptus wood, no full inventory dataset is publicly available. For this reason, the Brazilian dataset (Ecoinvent 2019) is used as a proxy dataset with an adaption of harvesting yield according to (Shibu et al. 2018). Long fibre content is assumed to use Central European softwood, as a Southern European dataset on softwood forestry is not available. Inventory datasets "softwood forestry, pine, Germany and softwood forestry, spruce, Germany" taken from (Ecoinvent 2019) are used.

Regarding Central European integrated production, both short fibre and long fibre need to be covered by Central European pulpwood. For Central European hardwood pulpwood, inventory datasets "hardwood forestry, oak, Germany and hardwood forestry, beech, Germany" taken from (Ecoinvent 2019) are used, as inventory datasets for further relevant Central European hardwood species (such as aspen, poplar) are not available. Long fibre content is based on inventory datasets "softwood forestry, pine, Germany and softwood forestry, spruce, Germany" taken from (Ecoinvent 2019).

► Integrated office paper production

Paper is made from the supplied wood in an integrated paper mill. The inventory dataset "paper production, woodfree, uncoated, at integrated mill" taken from (Ecoinvent 2019) is used. Data sources for prechains of externally procured energy and all relevant preliminary materials and auxiliary chemicals, including their prechains are taken from: (Ecoinvent 2019, Tiedemann et al. 2000, ifeu 2019). Externally provided energy (grid electricity) is adapted to the required geography for Northern, Central European and Southwest European integrated paper production.

#### 1.2.5.4 Integrated recycled office paper

The production of office paper from recycled fibres, covers the following processes:

- Sorting of waste paper and delivery for waste paper processing

Data used: (UBA 1998), energy prechains taken from (Ecoinvent 2019, ifeu 2019).

- Waste paper processing, DIP production

Data on final energy consumption, chemical demand and effluent (STP 2018).

The mix of energy carriers was selected so that it depicted an approximation of the typical German situation in DIP production, sources: (Gehr 2018, Gromke and Detzel 2006).

- Office paper production

Paper is manufactured from the DIP in the final process step. The data necessary for paper production comes from (STP 2018). Data sources for prechains of externally procured energy and all relevant preliminary materials and auxiliary chemicals, including their prechains are taken from: (Ecoinvent 2019, Tiedemann et al. 2000, ifeu 2019).

#### 1.2.5.5 Virgin tissue paper

The production of tissue paper from virgin fibres, non-integrated, includes the following processes:

- Wood provision from forestry

For the base scenarios, Northern European softwood as well as Eucalyptus from Latin America and Southern Europe is used as a raw material for pulping processes. For Northern pulpwood, the inventory dataset “softwood forestry, pine, Sweden” and “softwood forestry, spruce, Sweden” taken from (Ecoinvent 2019) are used. For Brazilian eucalyptus wood, the inventory dataset “hardwood forestry, eucalyptus ssp., planted forest management, Brazil” taken from (Ecoinvent 2019) are used. An average of the three Brazilian eucalyptus plantation regions available in the Ecoinvent database (Goiás, Minas Gerais, São Paulo) are used. For Iberian eucalyptus wood, no full inventory dataset is publicly available. For this reason, the Brazilian dataset is used as a proxy dataset with an adaption of harvesting yield according to (Shibu et al. 2018). For provision of North American softwood, no full inventory dataset is publicly available. For this reason, the Northern Europe softwood dataset is used as a proxy dataset.

Some additional forestry data sets are required for the technical variant scenarios with different origin of hardwood and softwood pulp. For Central European hardwood pulpwood, inventory datasets hardwood forestry, oak, Germany and hardwood forestry, beech, Germany taken from (Ecoinvent 2019) are used. For Central European softwood, inventory datasets softwood forestry, pine, Germany and softwood forestry, spruce, Germany taken from (Ecoinvent 2019) are used.

- Manufacture of market sulphate pulp

The manufacture of sulphate pulp in North America is based on the inventory dataset “sulfate pulp production, from hardwood, bleached” in Canada, Quebec taken from (Ecoinvent 2019). It covers the production of ECF bleached sulfate pulp from the kraft process. Underlying data refer to a mix of Canadian mills that pulp both softwood and hardwood. Production is assumed to take place 50 % in Canada and 50 % in the United States.

The manufacture of Latin American sulfate pulp production from eucalyptus is based on the inventory dataset "sulfate pulp production, eucalyptus, bleached, Latin America and the Caribbean" taken from (Ecoinvent 2019). It covers the production mix of ECF and total chlorine free (TCF) bleached sulfate pulp from the kraft process in Latin America. As no specific inventory dataset is publicly available for Iberian eucalyptus pulp production, this dataset is also used for Iberian eucalyptus pulp. However, external energy prechains (e.g. electricity) are adapted to Latin America and Iberia.

The manufacture of Northern sulphate pulp is based on "sulfate pulp production, from softwood, bleached, Europe" taken from (Ecoinvent 2019). It covers ECF and TCF kraft pulp, obtained from northern European softwood.

Data sources for prechains of externally procured energy and all relevant preliminary materials and auxiliary chemicals, including their prechains are taken from: (Ecoinvent 2019, Tiedemann et al. 2000, ifeu 2019).

► Refining of pulp

Before entering the paper machines, the dried pulp has to be refined and fibrillated. The energy consumption values used for the milling are based on (Bos 1999) and where required to be adapted to pulp type using experimental values based on (STP 2006).

► Tissue paper production

Paper is made from the supplied pulp in the last process step considered. The inventory data for tissue paper production is based on (EU COM PPP BREF 2015). Data sources for prechains of externally procured energy and all relevant preliminary materials and auxiliary chemicals, including their prechains are taken from: (Ecoinvent 2019, Tiedemann et al. 2000, ifeu 2019).

#### 1.2.5.6 Recycled tissue paper

The production of tissue paper from recycled fibres covers the following processes:

► Sorting of waste paper and delivery for waste paper processing

Data used: (UBA 1998), energy prechains taken from (Ecoinvent 2019, ifeu 2019)

► Waste paper processing, DIP production

Inventory data for DIP process is based on (EU COM PPP BREF 2015).

► Tissue paper production

Paper is manufactured from the DIP in the final process step under consideration. The data necessary for paper production come from (EU COM PPP BREF 2015). Data sources for prechains of externally procured energy and all relevant preliminary materials and auxiliary chemicals, including their prechains are taken from: (Ecoinvent 2019, Tiedemann et al. 2000, ifeu 2019).

### 1.2.6 Scenario overview

In the following, an overview of the scenarios based on the market analysis is given. Please note that these scenarios aim to represent an average situation of paper on the German market. Results for specific cases like the production of a single mill or company may differ. Such information can be found in separate LCA or carbon footprint studies like for example the recent studies by Holmen (Lindberg et al. 2018) or Metsä Tissue (AFRY 2021).

#### 1.2.6.1 Office paper

Scenario overview office papers (Cradle-to-gate):

Base scenarios are cradle-to-gate scenarios (for an illustration of system boundaries see 1.2.1) that aim for a comparison of virgin office paper and recycled office paper production technology, including assessment of variants from non-integrated production regarding pulp composition. The base scenarios are as follows:

- Virgin fibres, non-integrated production abbreviated: virgin non-integrated
- Virgin fibres, integrated production abbreviated: virgin integrated
- Recycled fibres, integrated production abbreviated: recycled integrated

Base scenarios are based on the outcome of relevant office paper type clusters as described in the previous paragraphs (see Table 3), where each of the base scenarios represent one of the market clusters. Both integrated and non-integrated office papers are assumed to consist of 85 % short fibres and 15 % long fibres. This office paper composition is intended to represent a typical office paper composition. Short fibre content of virgin non-integrated office paper is assumed to consist of Eucalyptus fibre for the base case, as based on short fibre import statistics both Latin American and Southern European Eucalyptus fibre plays a predominant role. Long fibre content originates predominantly from Northern European softwood, and a smaller share from North American softwood based on long fibre import statistics.

Regarding climate change an additional sensitivity analysis is added, in which the influence of the changing electricity mix in Germany, where most of the recycling paper production takes place, is being reviewed.

Additional scenarios regarding pulp composition and origin of fibres are included in the background report (UBA 2022).

#### 1.2.6.2 Tissue paper

Base scenarios are cradle-to-gate scenarios (for an illustration of system boundaries see 1.2.1) that aim at a technological comparison of virgin and recycled tissue paper production, including assessment of paper variants from non-integrated production regarding pulp composition.

The base scenarios are differentiated into 2 groups:

- Virgin fibres, non-integrated prod. abbreviated: virgin non-integrated
- Recycled fibres, integrated prod. abbreviated: recycled integrated

The cluster non-integrated recycled fibre that is shown in Table 4 is included into the integrated recycled fibre cluster, as underlying data for differentiation are assessed to be insufficient by the authors of the present study (e.g. typical transport distances of recycled fibres are not available from public data sources). Furthermore, the differences in environmental performance between integrated and non-integrated recycled fibre tissue papers is expected to be smaller than the difference between virgin fibre-based integrated versus non-integrated paper production.

Additional scenarios regarding pulp composition and origin of fibres are included in the background report (UBA 2022).

# 2 Life Cycle Assessment results

Stacked bar charts are used to show the environmental assessment. A differentiation is made here between different sectors of the paper production chain. In addition to the main processes, the individual sectors also contain all the relevant prechains such as energy provision or the provision of process materials, such as the transportation of raw materials or process materials (wood, recycled paper, caustic soda, etc.) if not shown separately. The following paragraphs describe how the results are broken down into sub-processes. For the sake of better orientation, the short name of sub-processes as used in the diagrams is additionally stated in square brackets in the enumeration of sub-processes.

All results shown refer to the framework conditions described in 1.2

**Non-integrated paper production using virgin fibres** is broken down into the following sub-processes:

- Wood provision (forestry/wastepaper)
- Transport of wood to pulp mill (transport wood/wastepaper)
- Pulp production (pulp/DIP)
- Transportation of pulp to paper mill (transport pulp)
- Paper production from pulp (paper production)
- Transport of paper to the German market (transport paper)

**Integrated paper production using virgin fibres** is broken down into the following sub-processes:

- Wood provision (forestry/wastepaper)
- Transport of wood to integrated mill (transport wood/wastepaper)
- Integrated paper production from wood (integrated paper mill)
- Transport of paper to the German market (transport paper)

**Paper production from waste paper** is broken down into the following sectors:

- Waste paper collection & sorting (wood/waste paper)
- Transport of waste paper to paper mill (transport wood/wastepaper)
- Production of DIP chemicals (prechains) (DIP) (pulp/DIP)
- Integrated DIP/paper production from recycled fibres (paper production)
- Transport of paper to the German market (transport paper)

All results shown refer to the production of one tonne of paper.

A note on significance: For studies intended to be used in comparative assertions intended to be disclosed to the public, ISO 14044 asks for an analysis of results for sensitivity and uncertainty. It's often not possible to determine uncertainties of datasets and chosen parameters by mathematically sound statistical methods. Hence, for the calculation of probability distributions of LCA results, statistical methods are usually not applicable or of limited validity. To define the significance of differences of results, an estimated significance threshold of 10% is chosen. This can be considered a common practice for LCA studies comparing different product systems. This means differences between product systems ≤ 10% are considered as insignificant.

## 2.1 Results office paper

### 2.1.1 Office paper base scenario results

#### 2.1.1.1 Office paper base scenario results: Climate Change, total CED, renewable CED & non-renewable CED

First, the environmental indicators associated primarily with the provision of energy, namely *the CED total, the CED renewable, the CED non-renewable* and *climate change* will be considered. In order to enable a more direct comparison between virgin and recycled paper, a weighted average result for the entire production of virgin paper is created in section 2.1.2.

Even though CED results do not represent assessed environmental impacts, they can deliver valuable additional information. The Cumulative Energy Demand of a product represents the direct and indirect energy use throughout its life cycle, in the case of these cradle-to-gate scenarios up to the factory gate. Thus, it includes the feedstock energy included in the product itself. As the final fate of the examined products is not included in the assessment when following a cradle-to-gate approach, the results of the feedstock energy dominated categories *CED total* and the *CED renewable* may deliver misleading information. For cradle-to-gate scenarios, the focus should be on *CED non-renewable.* By not accounting energy from renewable sources, though, it is possible to give the impression, that its use does not matter in view of the environment. That is of course not true. An additional result graph (Figure 6) is shown below. This figure shows the CED total without the feedstock energy.

Integrated recycled office papers are associated with a 62 % lower total primary energy demand than integrated virgin office papers and a 72 % lower total primary energy demand than non-integrated virgin office papers. Furthermore, integrated recycled office papers are associated with a lower, renewable and non-renewable primary energy demand than non-integrated virgin office papers. Total and renewable primary energy demand of recycled papers is also lower than that of integrated office papers, but on a similar level regarding non-renewable CED. When substracting the feedstock energy it can be shown, that in regard to total process energy used, the recycled office papers are associated with a lower total energy demand than both types of virgin office papers.

Correspondingly to the results of *CED non-renewable*, greenhouse gas emissions *(climate change)* associated with office paper production are 31 % lower for recycled papers than for non-integrated virgin papers, but in the same order of magnitude than integrated office papers. For a good part, the latter finding is related to the very high share of biomass-based process energy in integrated virgin paper production through the use of black liquor, bark as well as wood chips as energy sources.

The highest contributions to the overall results of office papers for the indicators discussed here are for all paper types associated with the paper making in case of papers from non-integrated production and the overall paper mill process in case of papers from integrated production.

Further important life cycle steps are the pulping and pulp transports and DIP process for papers from non-integrated production. Pulp transports are especially visible due to long-distance transports of Iberian and Latin American eucalyptus pulp. Wood transports are hardly visible regarding primary non-renewable energy and climate change, except Southwestern European virgin papers, where some eucalyptus wood imports from Brazil (~13 % of Southwestern European eucalyptus wood supply) show some contribution.

**Note on purchased electricity from renewable sources**

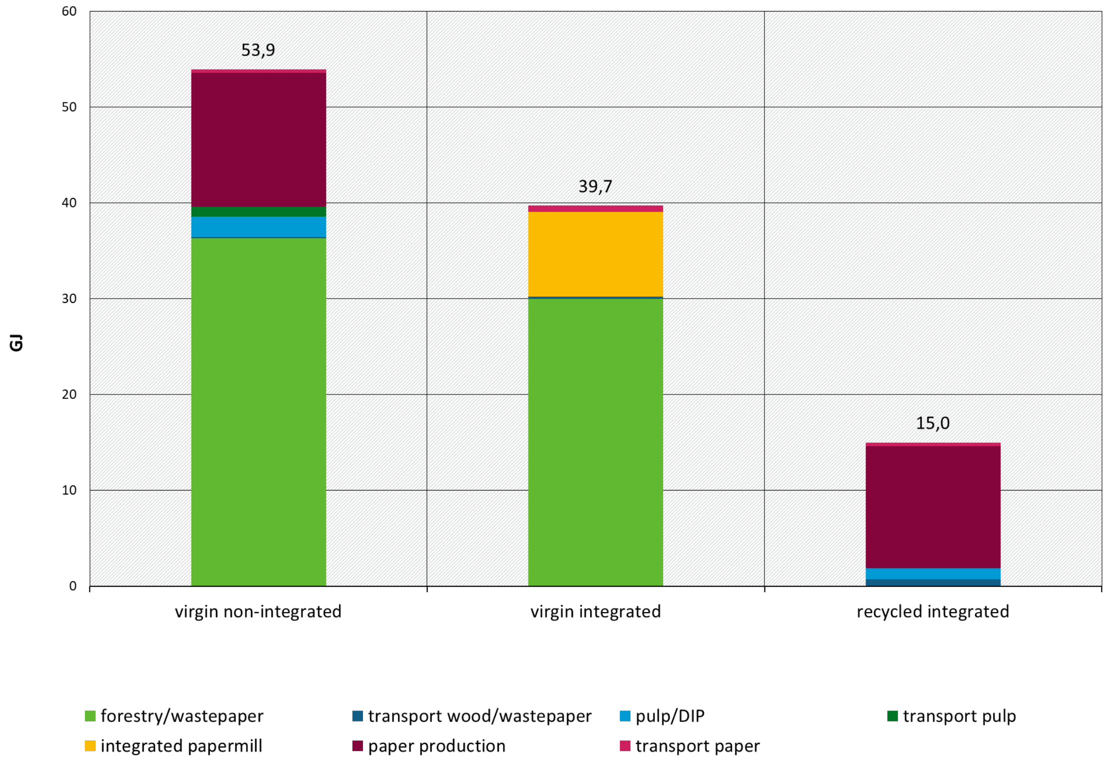
Some fibre and paper mills use supplier specific purchased energy by buying green certificates. In order to avoid double counting, these would have to be deducted from the electricity mixes used in all other processes. This is not possible in the context of this LCA, not only is there no residual mix available, the aggregation of many background processes also makes it impossible to replace the average electricity mixes applied. Therefore, externally purchased electricity from renewable sources is not considered even though on the level of individual production sites, the purchase of renewable energies has a positive effect on the carbon impact. This approach is compliant with the ISO standards for Life Cycle Assessment ISO 14040 and ISO 14044.

**Note on the assessment of climate change in regard to the treatment of biogenic carbon**

In recent years, the calculation of carbon impacts of forest biomass is questioned especially regarding burning the wood for energy generation. This discussion covers several carbon-related aspects: carbon contained in wood with emphasis on the timing of biomass growth versus the timing of emissions, carbon from land use change, and reductions in the carbon storage capacity of forests. There have been developed and exemplified dynamic approaches that consider temporary effects of biogenic carbon dioxide emissions on climate change until being captured again or carbon budgets models that calculate carbon fluxes under changing forest management systems (Tellnes et al. 2017; Hoxha et al. 2020, Matthews et al. 2014). This valuable research shows the need for a critical consideration of the classification of biomass by the European Union Emissions Trading Scheme, which currently gives preferential treatment to greenhouse gas emissions associated with biomass combustion. Even though dynamic modeling of biogenic carbon fluxes in LCA is desirable, current calculation models are associated with high variability and different approaches provide different results. Moreover, there is currently no scientific consensus on which method is the most suitable for use in LCAs (Tellnes et al. 2017; Hoxha et al. 2020; UBA 2016). The study of (Matthews et al. 2014) carried out for the European Commission concludes that due to the variability of biogenic sources in terms of associated GHG emissions, a qualitative assessment using a decision tree is best suited to identify risks related to GHG emissions. Since the location of forests claimed for paper production is uncertain (see section 3), the question also arises within this study as to exactly what potential forest carbon losses paper production would be responsible for. Therefore, risk of land use change and principles of forest management that counteract a positive carbon balance are discussed qualitatively in section 3. Quantifying the carbon dynamics associated with paper production or uptake using currently developed models to calculate the forest dynamics of the forest area associated with paper production would more appropriately be the subject of a separate research project.

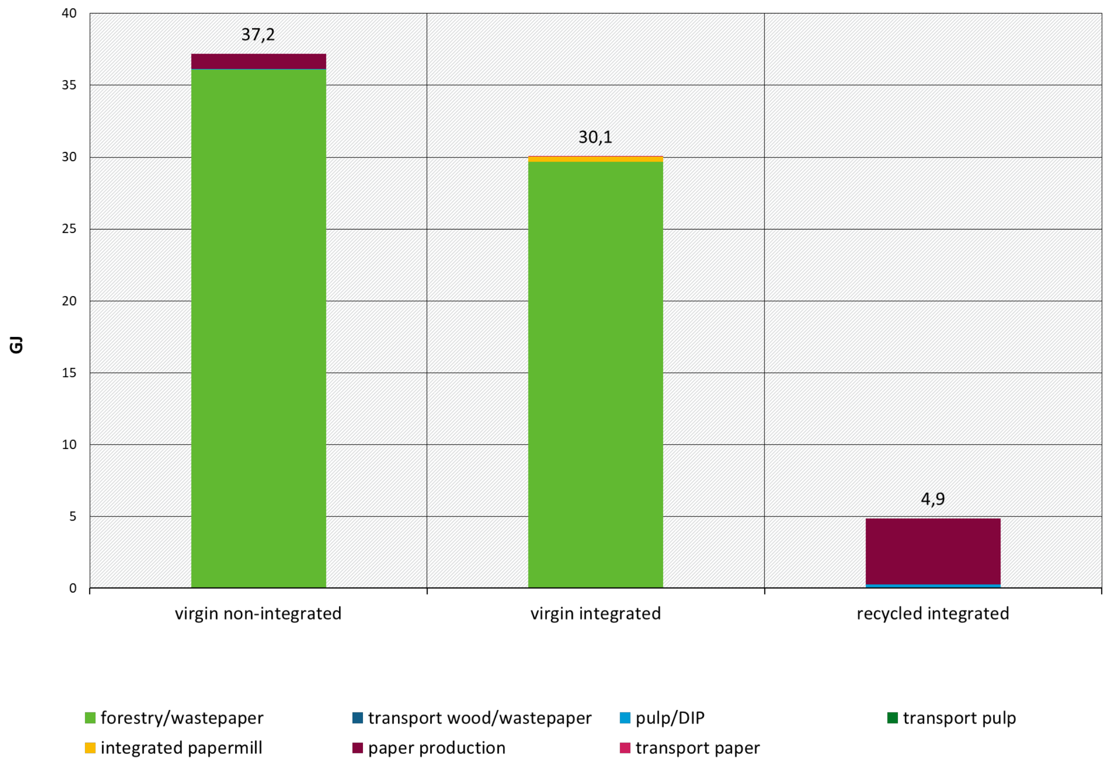
**Therefore, this study follows the rules of currently existing LCA methods. Following the approach of ILCD 2010, PAS 2050 and ISO-14067, biogenic GHG emissions and removals within the 100-year period are considered as if they were released or removed at the beginning of the assessment period.**

**Figure 2: Cumulative Energy Demand (CED) total, 1000 kg office paper, base scenarios**



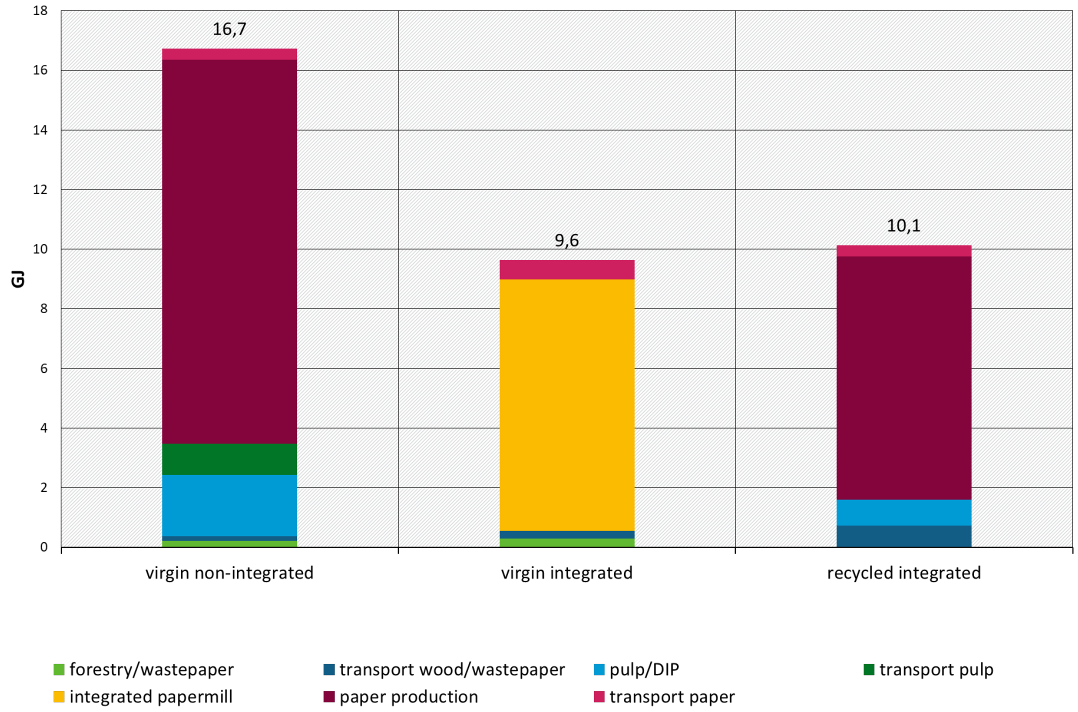

Source: (Own depiction 2021, ifeu)

**Figure 3: Cumulative Energy Demand (CED) renewable, 1000 kg office paper, base scenarios**



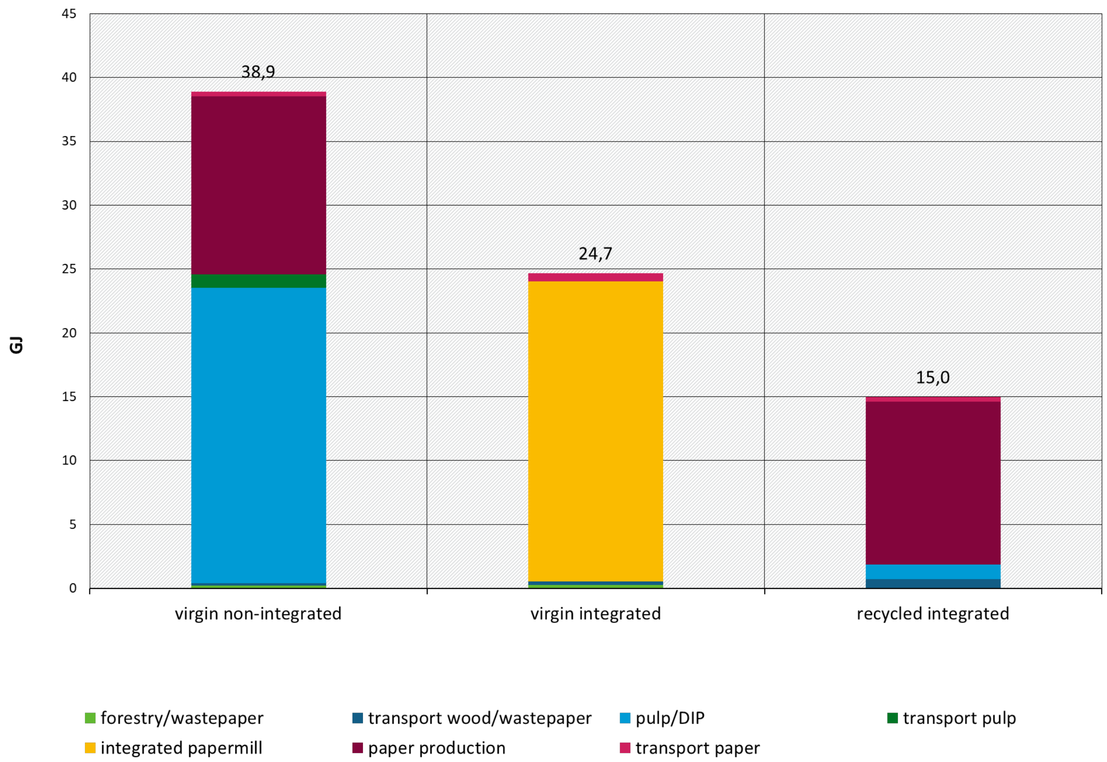

Source: (Own depiction 2021, ifeu)

**Figure 4: Cumulative Energy Demand (CED) non-renewable, 1000 kg office paper, base scenarios**



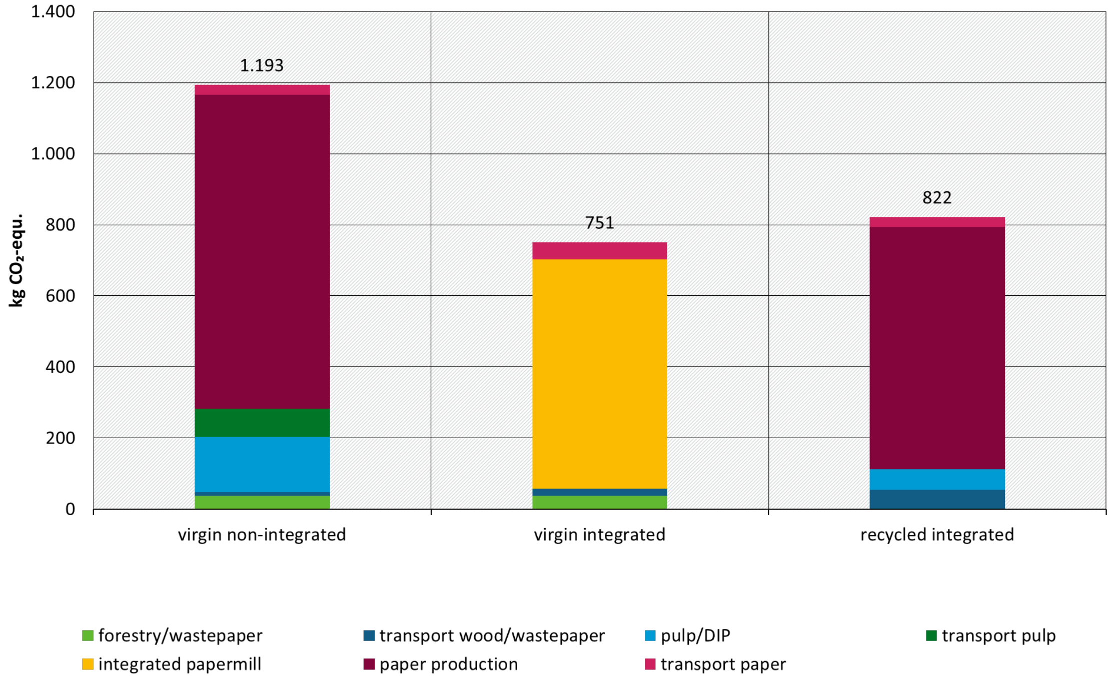

Source: (Own depiction 2021, ifeu)

**Figure 5: Cumulative Energy Demand (CED) total without feedstock energy, 1000 kg office paper, base scenarios**




Source: (Own depiction 2021, ifeu)

**Figure 6: Climate Change, 1000 kg office paper, base scenarios**




Source: (Own depiction 2021, ifeu)

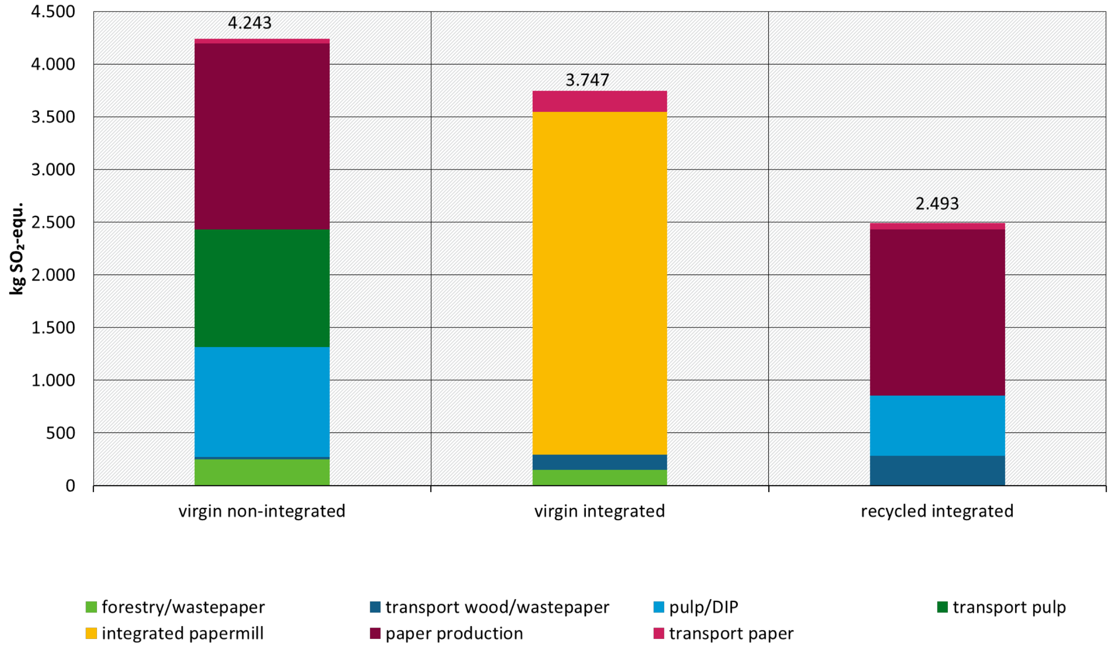
See section 2.1.2 for the comparison of impact results for average virgin paper and recycled paper.

#### 2.1.1.2 Office paper base scenario results: Acidification & Terrestrial Eutrophication

In this section, the environmental indicators related to non-carbon dioxide air emissions, but related to nitrogen and sulfur compounds, *Acidification* and *Terrestrial Eutrophication*, are considered. Those compounds are both typically associated with transports as well as combustion processes.

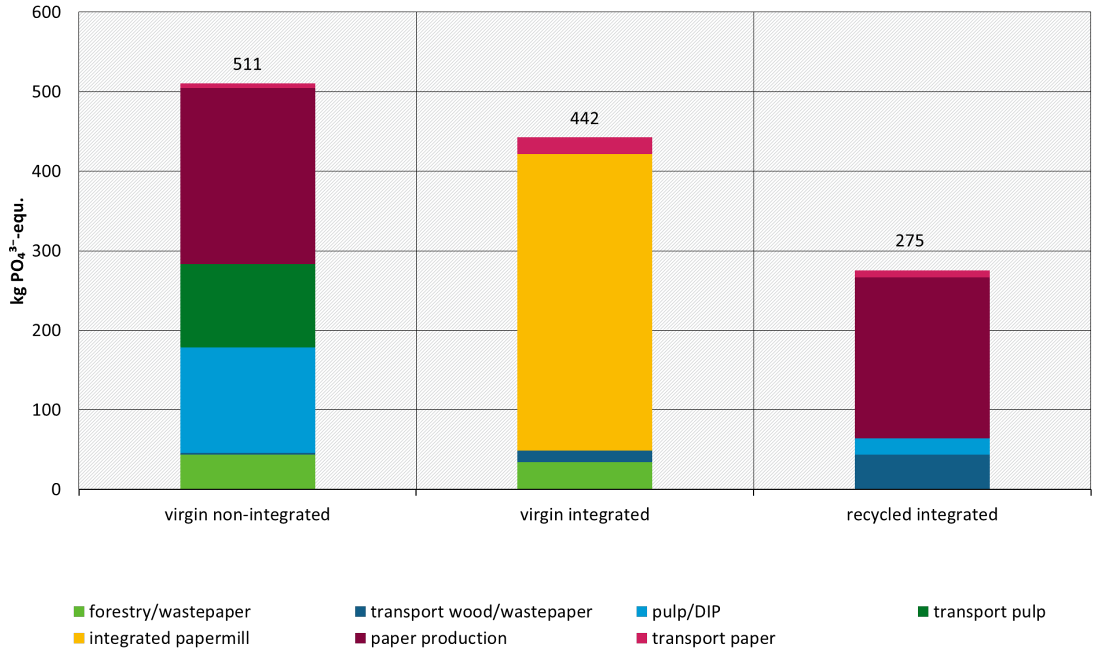
Integrated recycled office papers from integrated production are associated with 41% and 46% lower (Acidification and Terrestrial Eutrophication, respectively) environmental impacts than non-integrated virgin office papers and 33% and 38% lower impacts than integrated virgin office papers in the named indicators. For a good part, this is related to the high share of biomass-based process energy required for the integrated pulp and paper production, due to the release of sulfur and nitrogen content originating from biomass and the thermal nitrogen oxide generation during combustion processes for energy generation. Considerable transport processes contribute to both sulfur and nitrogen compounds emitted to air, especially in case of non-integrated virgin papers (pulp transports e.g. from Iberia and Latin America).

**Figure 7: Acidification, 1000 kg office paper, base scenarios**




Source: (Own depiction 2021, ifeu)

**Figure 8: Terrestrial Eutrophication, 1000 kg office paper, base scenarios**




Source: (Own depiction 2021, ifeu)

See section 2.1.2 for the comparison of impact results for average virgin paper and recycled paper.

#### 2.1.1.3 Office paper base scenario results: Water-related results

Looking at water-related environmental impacts and water-related environmental indicators provides additional insight into of the environmental performance of paper production. This includes aquatic eutrophication, adsorbable organic halogenated compounds (AOX), and process water demand (freshwater).

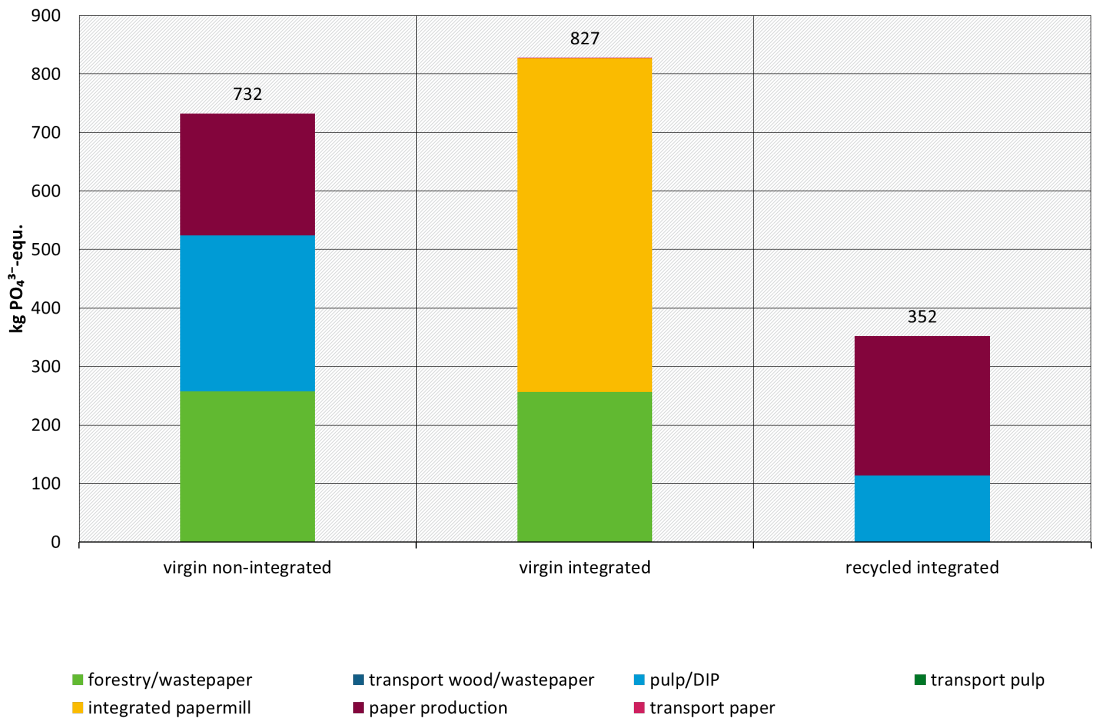
For the three environmental indicators in the focus here, recycled paper results are considerably lower (at least 50 % lower or more in aquatic eutrophication, and even higher for the other two water-related indicators) than all virgin papers examined.

As for the virgin papers, their contribution to aquatic eutrophication is of a similar order of magnitude regardless their production type integrated or non-integrated. As underlying emissions to water (such as COD) are largely related to the use of process chemicals, aquatic eutrophication related to overall paper production processes (i.e. integrated mill versus sum of pulping and papermaking in case of non-integrated production) is somewhat comparable per equal amount of virgin fibres. On the other hand, forestry does contribute as well due to nitrogen and phosphor compounds emitted to water, thus e.g. depending on different wood harvesting yields, differences according to pulpwood types are observed in aquatic eutrophication.

The picture is different for process water demand (freshwater). The freshwater demand for the production of recycled papers is 75% lower than for virgin non-integrated and 80% lower than for virgin integrated papers (Figure 10). The non-integrated production is associated with lower freshwater demand than the papers from integrated production. A clear picture on the other hand is the comparison of virgin office papers versus recycled office papers, where obviously DIP production requires considerably less freshwater input than primary pulping processes. In order to enable a more direct comparison between virgin and recycled paper with regard to process water demand (freshwater demand), a weighted average result for the entire production of virgin paper is created in section 2.1.2.

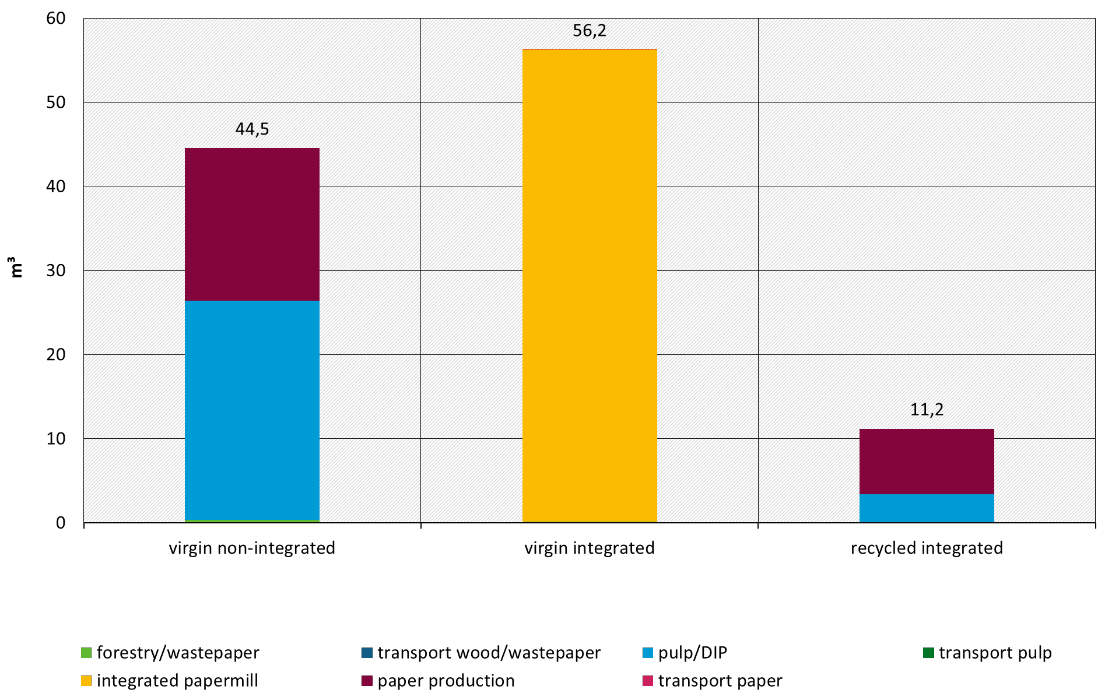
AOX results indicate that less halogenated organic compounds are emitted to water in case of non-integrated virgin office paper production than in integrated virgin paper production processes. This finding may also depend on different shares of chlorine compounds-based pulping processes (thus varying pulping/bleaching technologies and related process chemicals required) throughout integrated mills and non-integrated paper production chains.

**Figure 9: Aquatic Eutrophication, 1000 kg office paper, base scenarios**



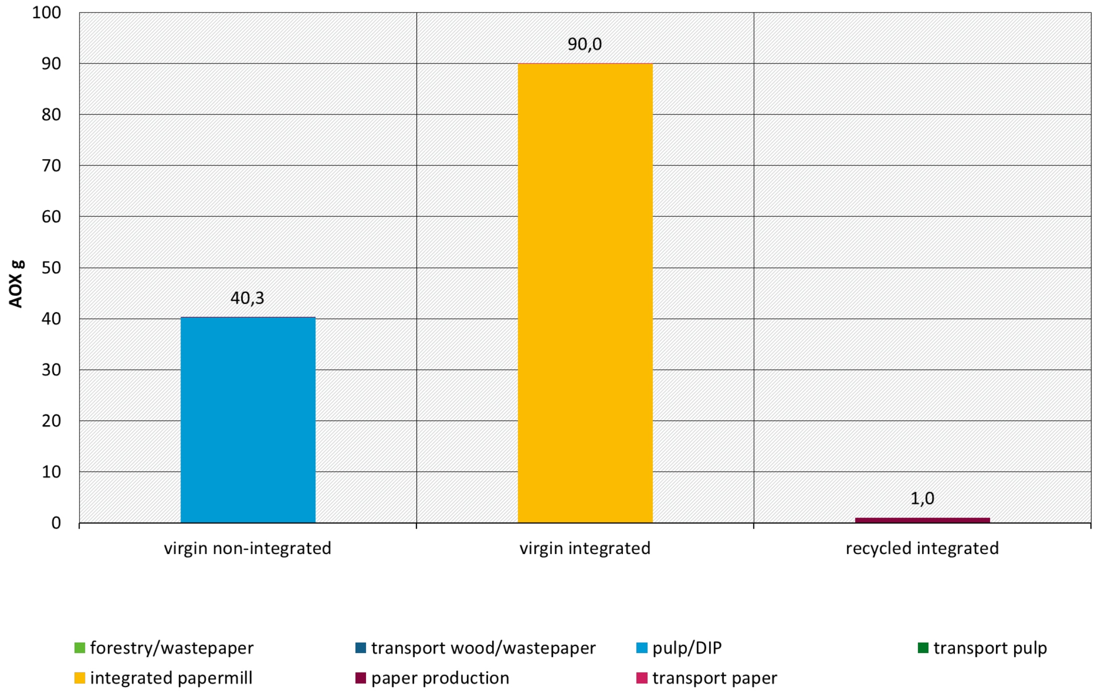

Source: (Own depiction 2021, ifeu)

**Figure 10: Freshwater Demand, 1000 kg office paper, base scenarios**




Source: (Own depiction 2021, ifeu)

**Figure 11: Adsorbable Organic Halogenated Compounds (AOX), 1000 kg office paper, base scenarios**




Source: (Own depiction 2021, ifeu)

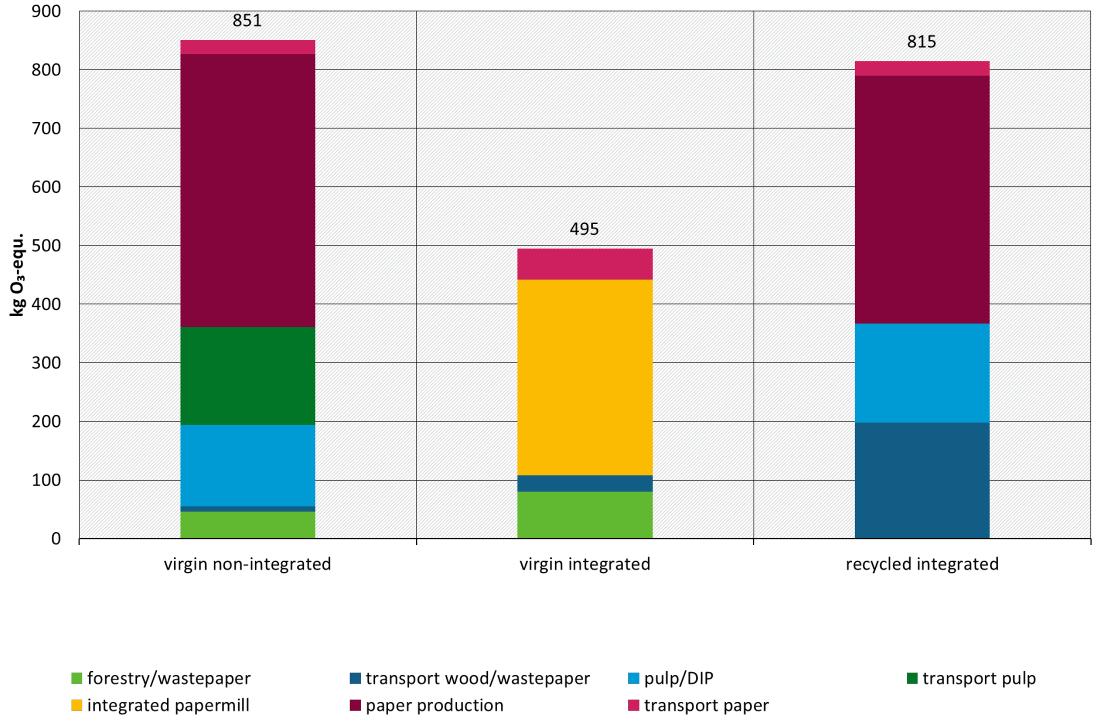
See section 2.1.2 for the comparison of impact results for average virgin paper and recycled paper.

#### 2.1.1.4 Office paper base scenario results: Human Health-related results

Environmental impact indicators *Photo-oxidant formation* and *fine particulate matter (PM 2.5)* are environmental indicators that are also health-related. This section provides a closer look into the environmental performance of office papers regarding those aspects.

Integrated office papers are associated with lower Photo-oxidant formation than non-integrated, both virgin papers and recycled papers. This finding is related to organic air emissions (VOC and NMVOC) associated with combustion processes / energy prechains in general. Some of those air emissions are also transport-related, thus besides the energy-intensive processing steps of pulping and papermaking and integrated paper mills, also pulpwood/wastepaper/pulp transports show contributions. **However, comparative findings in this aspect have to be handled with care, as data symmetry within the various individual datasets contributing to this result may not be fully given based on the inventory data currently available.**

**Figure 12: Photo-oxidant formation, 1000 kg office paper, base scenarios**

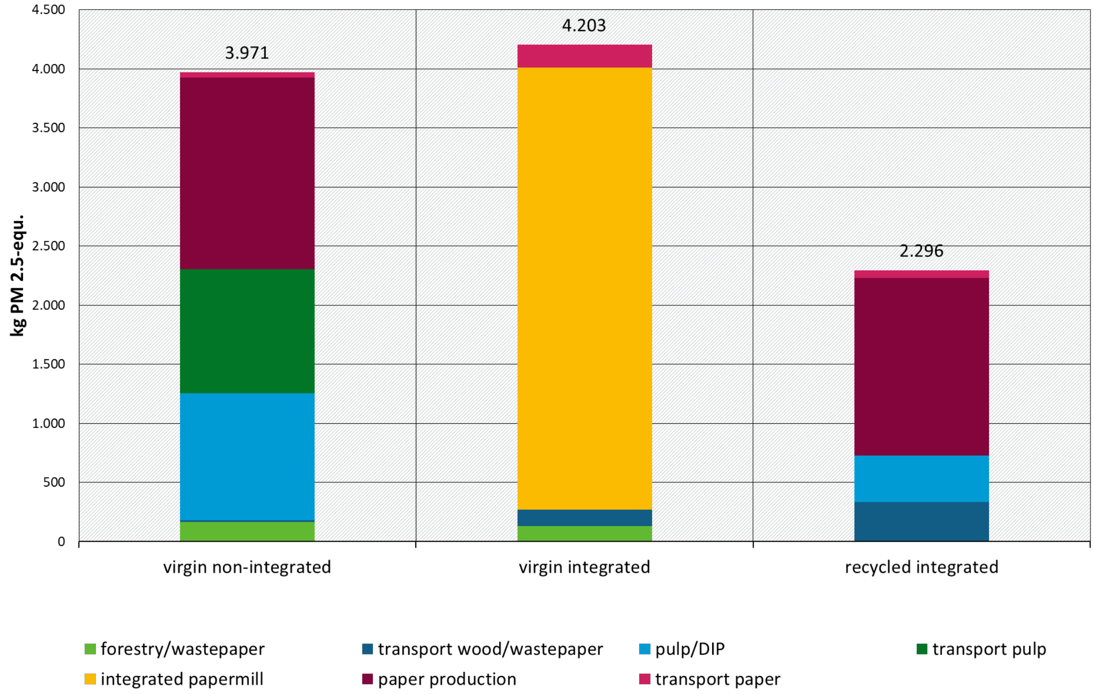



Source: (Own depiction 2021, ifeu)

Recycled office papers are associated with lower fine particulate matter (PM 2.5) than all examined virgin papers. This finding is for a good part related to sulphur oxides and nitrogen oxides emissions. Main sources of those air emissions are combustion processes, for energy generation, and to a smaller degree fuel combustion processes in transports. For the latter reason, additional impact is observed for wood transports to Southwest European integrated paper mills (due to some pulpwood imports from Latin America and thus long-distance overseas transport processes). To some extent, this is also true for non-integrated virgin papers (long-distance pulp imports e.g. from Latin America).

Differences related to combustion processes may originate from different levels of flue gas cleaning, depending on local air quality requirements and/or age of the energy generating installation.

**Figure 13: Particulate Matter (PM 2.5), 1000 kg office paper, base scenarios**




Source: (Own depiction 2021, ifeu)

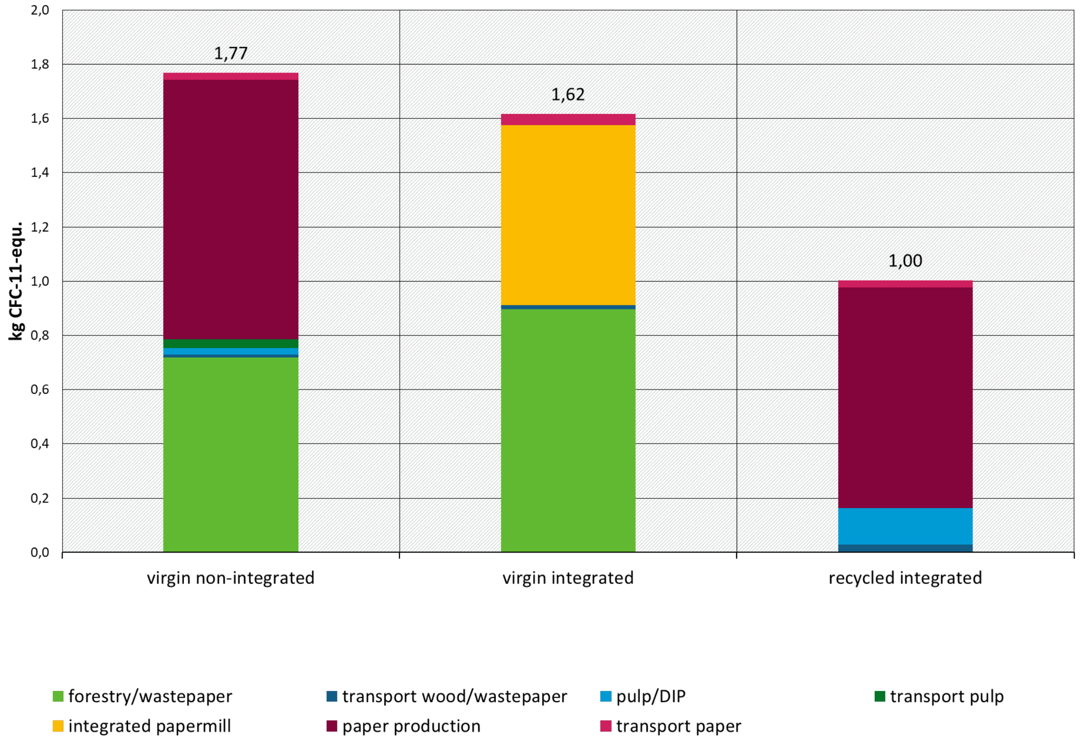
See section 2.1.2 for the comparison of impact results for average virgin paper and recycled paper.

#### 2.1.1.5 Office paper base scenario results: Ozone Depletion

Recycled office papers are associated with clearly lower ozone depletion impacts than both integrated and non-integrated virgin papers examined. In case of papers from virgin integrated production, the largest contributing emission to ozone depletion is nitrous oxide ($N_2O$) emitted to air from forestry operations. In case of virgin non-integrated paper production, the nitrous oxide emission is not the largest but the second-largest contribution.

Recycled office papers on the other hand show the highest contribution related to energy generation processes, where also nitrous oxide is emitted as a result of combustion processes (both biogenic and fossil fuels).

Figure 14: Ozone depletion, 1000 kg office paper, base scenarios




Source: (Own depiction 2021, ifeu)

See section 2.1.2 for the comparison of impact results for average virgin paper and recycled paper.

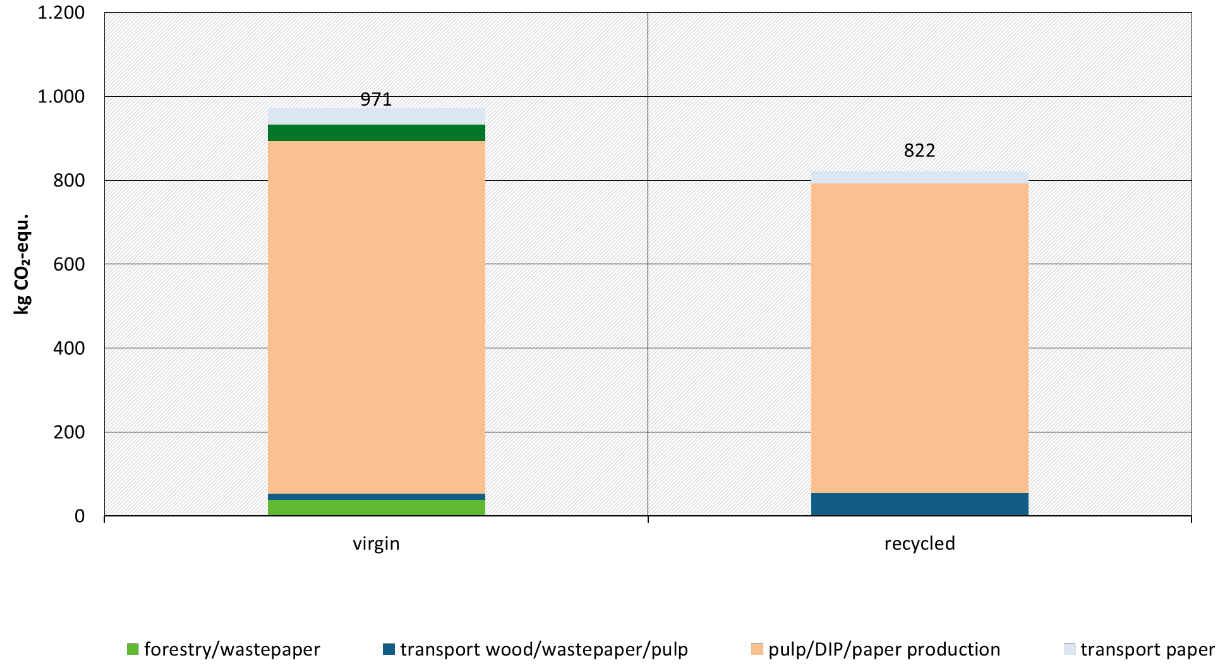
### 2.1.2 Results of the comparison of virgin paper and recycled paper

The presentation of the results in section 2.1.1.1 is based on the selection of clusters in section 1.2.4. This means that virgin papers are differentiated according to two types of production (non-integrated and integrated), whereas recycled papers are not differentiated because the share of non-integrated recycled papers is too insignificant to form a separate cluster. In order to enable a more direct comparison between virgin and recycled paper, a weighted average result for the entire production of virgin paper is therefore created for this comparison. The results of which are presented in Figure 15, Figure 16 an Figure 17.

Figure 15 shows the results for climate change. The impacts of recycled paper from integrated production are 15 % lower than those of the average virgin paper.

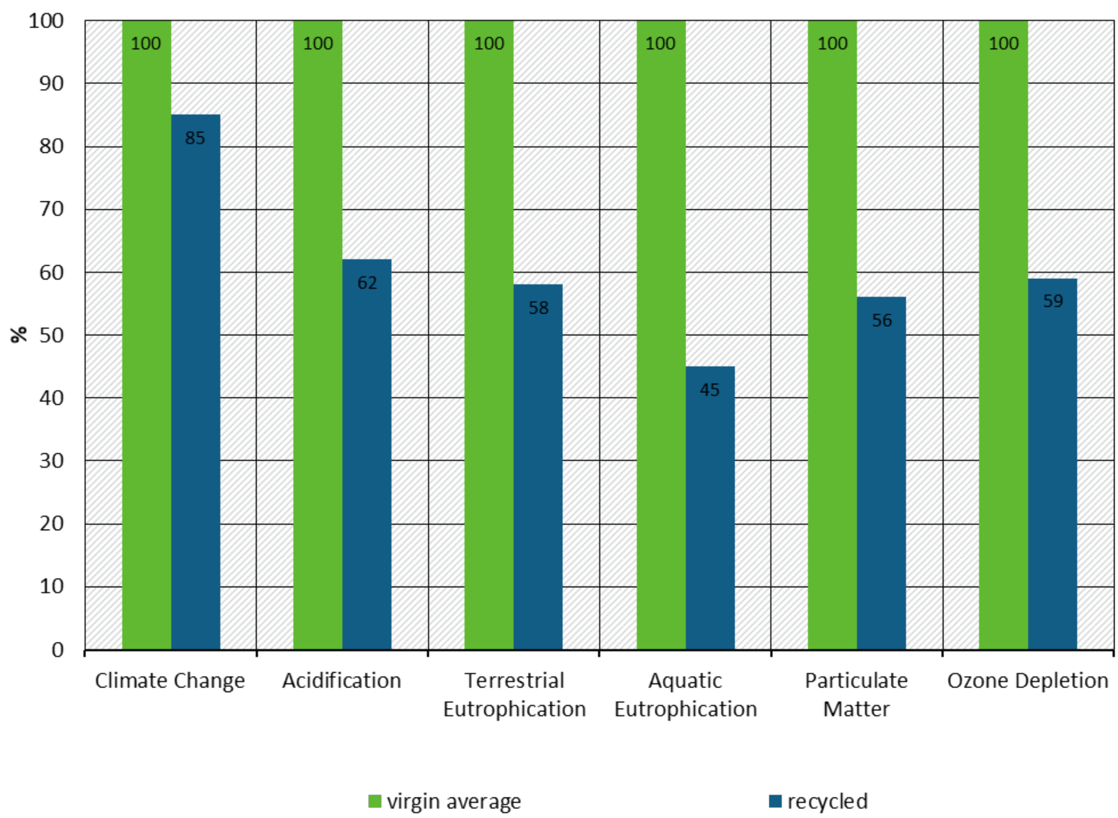
Figure 16 and Figure 17show the relative results of the environmental impact categories and inventory categories.  All these impact and inventory results of recycled paper from integrated production are also significantly lower than those of the average virgin paper.

**Figure 15: Climate change, 1000 kg office paper, comparison virgin vs recycled**



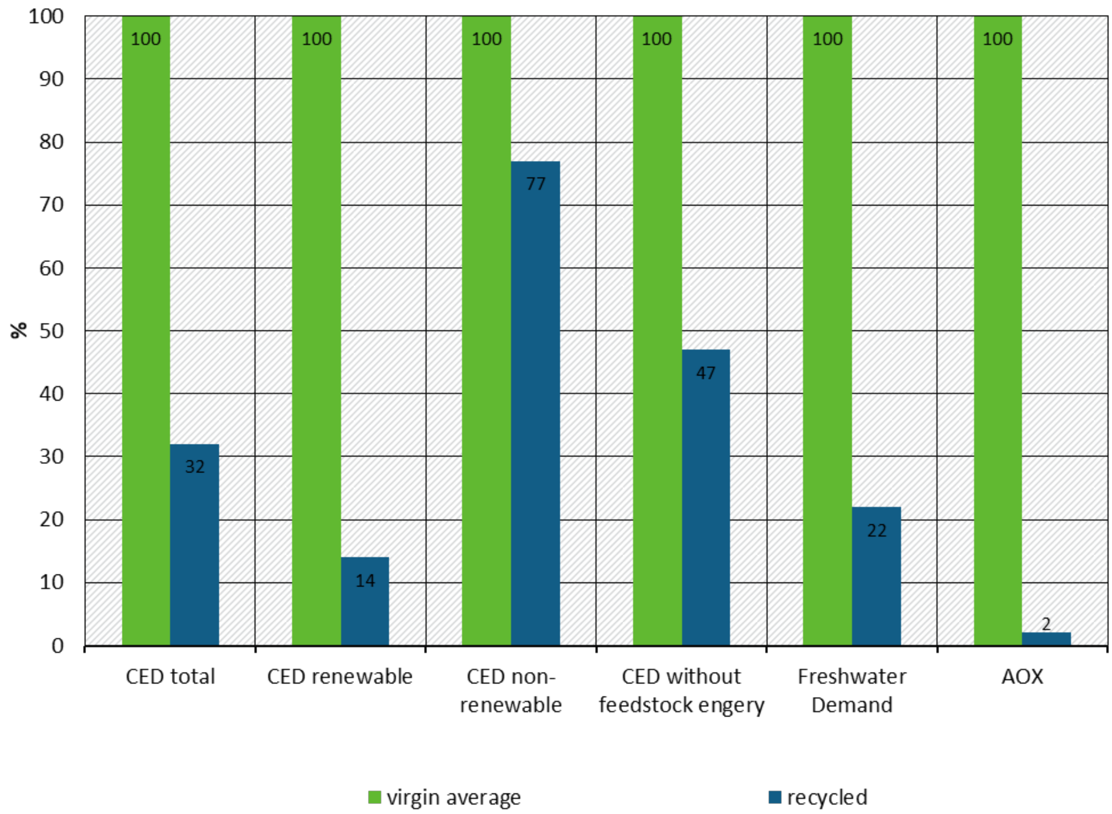

Source: (Own depiction 2021, ifeu)

**Figure 16: Environmental impact categories, 1000 kg office paper, comparison virgin vs recycled**




Source: (Own depiction 2021, ifeu)

**Figure 17: Inventory categories, 1000 kg office paper, comparison virgin vs recycled**




Source: (Own depiction 2021, ifeu)

### 2.1.3 Results of the sensitivity analysis regarding potential future electricity production

The results presented in section 2.1.1.1 show that the use of non-renewable energy has a large impact on the results of the environmental impact category climate change. Especially the recycled paper is mainly produced within Germany, where a transition from a domination of fossil-based electricity production to a higher share of renewable energy sources is taking place.

In this sensitivity, a potential future electricity production mix for the year 2030 in Germany is applied for the scenarios for virgin non-integrated paper production and recycled integrated paper production. The integrated paper production utilises mainly biomass-based process energy through the use of black liquor, bark as well as wood chips as energy sources instead of purchased electricity. For this reason, and because no prognosis regarding the development of electricity production in Northern and Southwestern Europe is available, the scenario for virgin integrated office paper production remains unchanged.

The potential German electricity mix for the year 2030 is taken from "Politikszenarien für den Klimaschutz VII" (UBA 2018), a publication by the German Environment Agency that includes predictions for the development of the German electricity mix. This potential electricity mix does not include the consequences of the phasing out of coal, as this will be done until 2038. The use of a potential future electricity for an even later date like 2040 or 2050 is not considered as this would not be appropriate for an assessment without also considering potential changes of other parameters like production or transport processes or a changed paper market so far into the future.

The scenario used for this sensitivity is the “With Additional Measures Scenario (WAMS)”, which includes the additional measures by the German government in Germany’s Climate Action Programme 2020 and its National Action Plan for Energy Efficiency in December 2014 in order to meet the target of reducing its GHG emissions by 40 % by 2020 compared to 1990.

The mix of energy sources in this scenario is as follows:

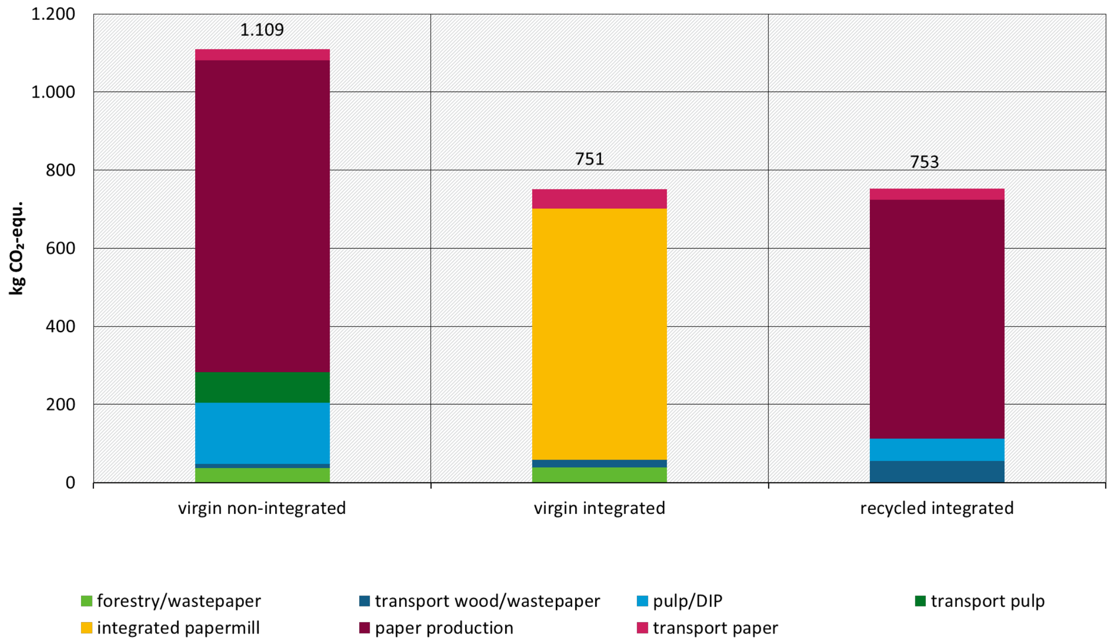
- Nuclear energy 0 %
- Lignite 14,1 %
- Hard coal 11,4 %
- Natural gas 12,4 %
- Others 2,7 %
- Renewables 58,7 %
- Pumped-storage hydroelectricity 0,7 %

The emission factor for this potential 2030 electricity mix is 408 g $CO_2$-equ./kWh, whereas the one for the 2015 electricity mix applied in the base scenarios is 581 g $CO_2$-equ./kWh.

Considering the significance threshold of 10 % for the comparison of the results, the results presented in Figure 18 show that the climate change impact of recycled paper from integrated production is on the same level as that of the base scenario. (753 kg $CO_2$-equ. vs. 822 kg $CO_2$-equ.). In this analysis, the climate change impact of recycled paper is also on the same level as that of the unchanged scenario for virgin office paper from integrated production (753 kg $CO_2$-equ. vs. 751 kg $CO_2$-equ.).

The impacts of virgin paper from non-integrated production are also on the same level as those of the base scenario, but still considerably higher than those of virgin paper from integrated production and recycled paper.

**Figure 18: Climate change, 1000 kg office paper, sensitivity 2030**



Source: (Own depiction 2021, ifeu)

#### 2.1.4 Further office paper variant scenario results

The results of further office paper variant scenarios are presented in the background report (UBA 2022) of this study.

## 2.2 Results tissue paper

### 2.2.1 Tissue paper base scenario results

#### 2.2.1.1 Tissue paper base scenario results: Climate Change, total CED, renewable & non-renewable CED

First, the environmental indicators associated primarily with the provision of energy, namely the *CED total, CED renewable, the CED non-renewable* and *climate change* will be considered.

Recycled tissue papers are associated with a lower total (-70%), renewable (-97%) than non-integrated virgin tissue papers. For non-renewable primary energy demand, the results are on the same level in both production types. Greenhouse gas emissions associated with tissue paper production are lower (-12 %) for recycled papers than for non-integrated virgin tissue papers.

Highest contributions (higher than 70 %) to the overall results of tissue papers for both indicators discussed here are associated with the papermaking. Further visible life cycle steps are the pulping and pulp transports and DIP process. Pulp transports are visible due to long-distance transports of Iberian and Latin American eucalyptus pulp.

**Note on purchased electricity from renewable sources**

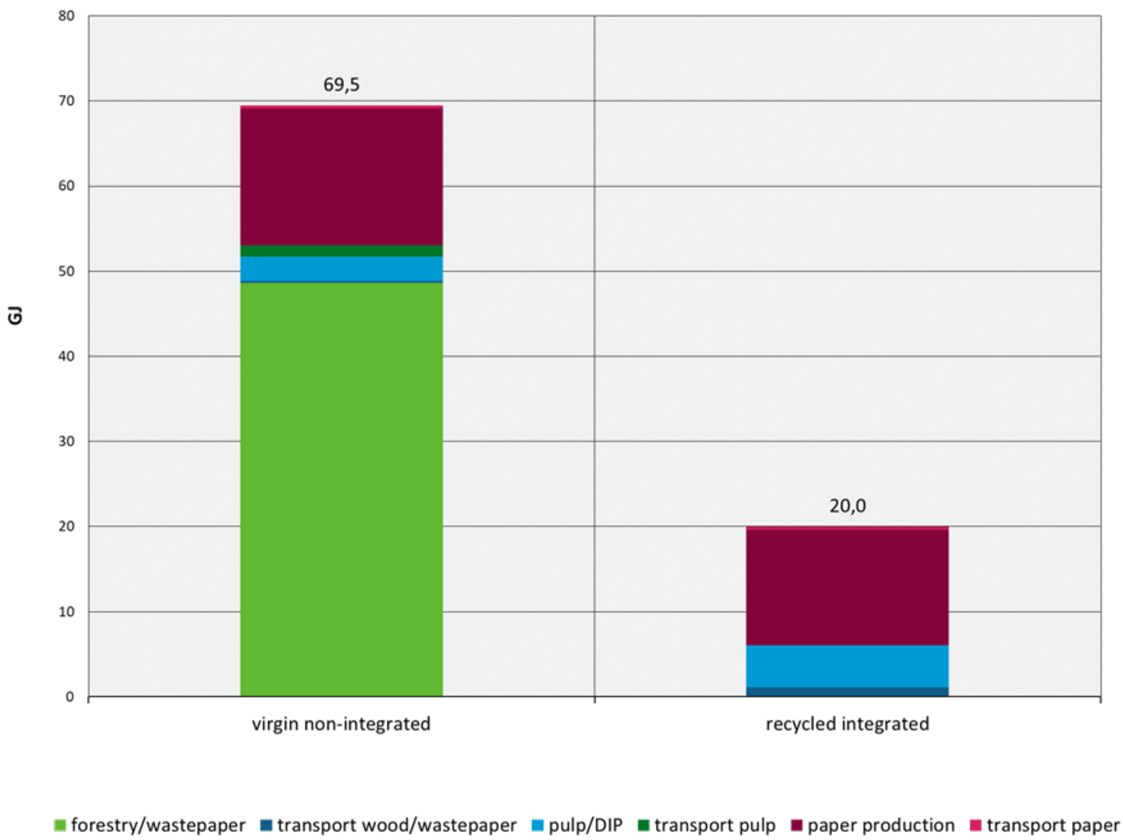
Some fibre and paper mills use supplier specific purchased energy by buying green certificates. In order to avoid double counting, these would have to be deducted from the electricity mixes used in all other processes. This is not possible in the context of this LCA, not only is there no residual mix available, the aggregation of many background processes also makes it impossible to replace the average electricity mixes applied. Therefore, externally purchased electricity from renewable sources is not considered even though on the level of individual production sites, the purchase of renewable energies has a positive effect on the carbon impact. This approach is compliant with the ISO standards for Life Cycle Assessment ISO 14040 and ISO 14044.

**Note on the assessment of climate change in regard to the treatment of biogenic carbon**

In recent years, the calculation of carbon impacts of forest biomass is questioned, especially regarding burning the wood for energy generation. This discussion covers several carbon-related aspects: carbon contained in wood with emphasis on the timing of biomass growth versus the timing of emissions, carbon from land use change, and reductions in the carbon storage capacity of forests. There have been developed and exemplified dynamic approaches that consider temporary effects of biogenic carbon dioxide emissions on climate change until being captured again or carbon budgets models that calculate carbon fluxes under changing forest management systems (Tellnes et al. 2017; Hoxha et al. 2020, Matthews et al. 2014). This valuable research shows the need for a critical consideration of the classification of biomass by the European Union Emissions Trading Scheme, which currently gives preferential treatment to greenhouse gas emissions associated with biomass combustion. Even though dynamic modeling of biogenic carbon fluxes in LCA is desirable, current calculation models are associated with high variability and different approaches provide different results. Moreover, there is currently no scientific consensus on which method is the most suitable for use in LCAs (Tellnes et al. 2017; Hoxha et al. 2020; UBA 2016). The study of (Matthews et al. 2014) carried out for the European Commission concludes that due to the variability of biogenic sources in terms of associated GHG emissions, a qualitative assessment using a decision tree is best suited to identify risks related to GHG emissions. Since the location of forests claimed for paper production is uncertain (see section 3), the question also arises within this study as to exactly what potential forest carbon losses paper production would be responsible for. Therefore, risk of land use change and principles of forest management that counteract a positive carbon balance are discussed qualitatively in section 3. Quantifying the carbon dynamics associated with paper production or uptake using currently developed models to calculate the forest dynamics of the forest area associated with paper production would more appropriately be the subject of a separate research project.

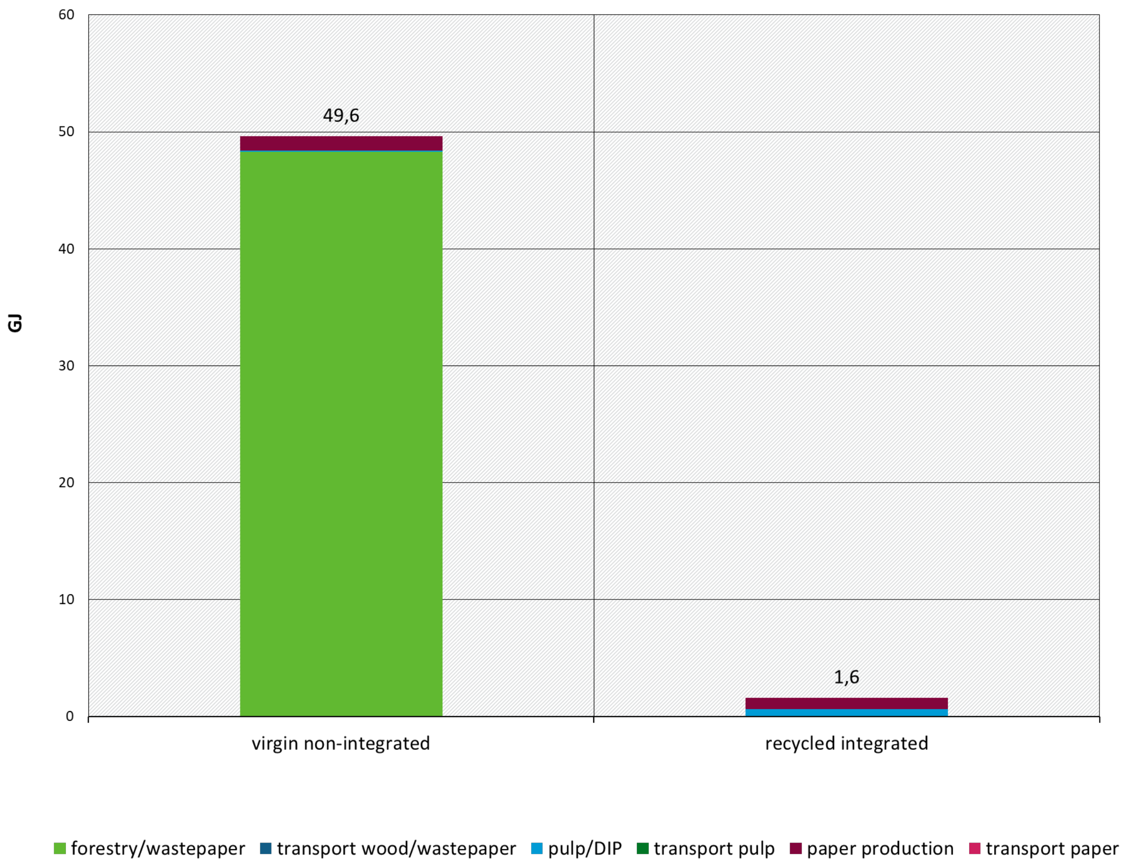
**Therefore, this study follows the rules of currently existing LCA methods. Following the approach of ILCD 2010, PAS 2050 and ISO-14067, biogenic GHG emissions and removals within the 100-year period are considered as if they were released or removed at the beginning of the assessment period.**

**Figure 19: Cumulative Energy Demand (CED) total, 1000 kg tissue paper, base scenarios**



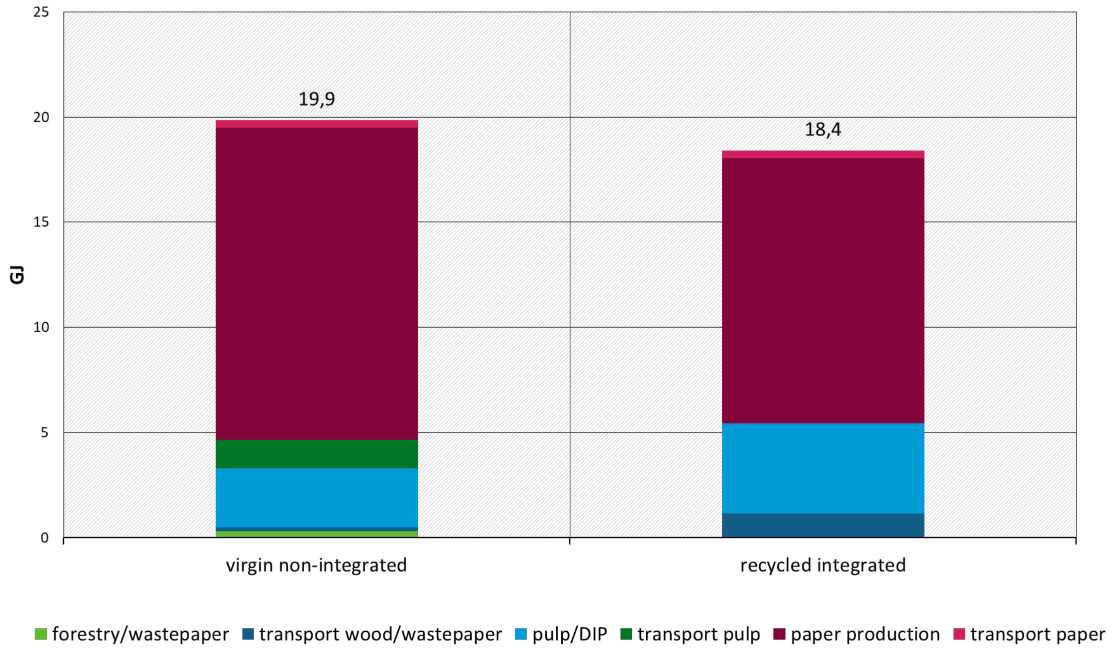

Source: (Own depiction 2021, ifeu)

**Figure 20: Cumulative Energy Demand (CED) renewable, 1000 kg tissue paper, base scenarios**



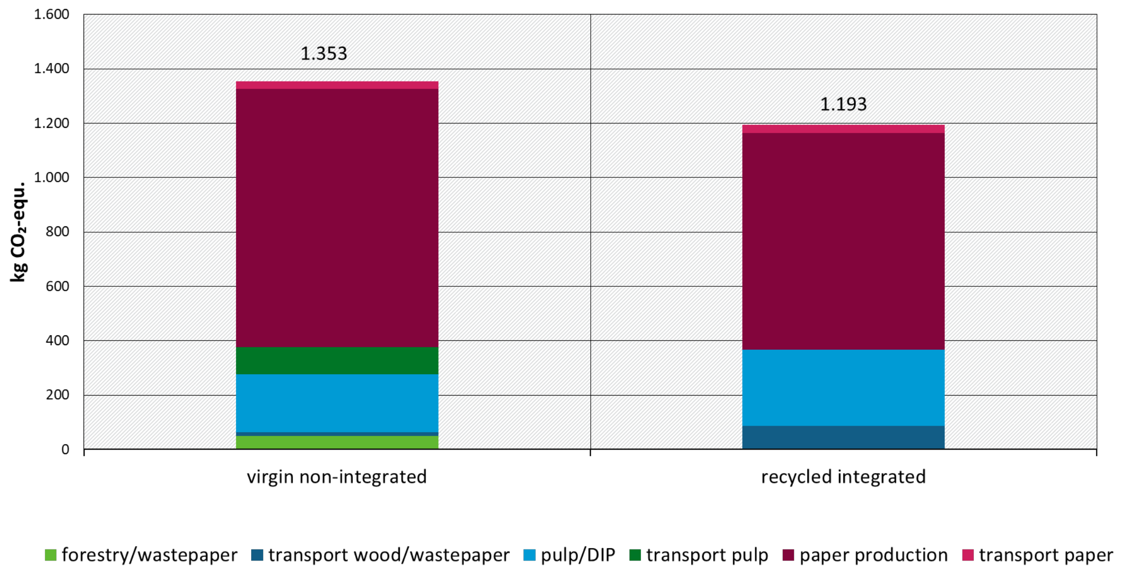

Source: (Own depiction 2021, ifeu)

**Figure 21: Cumulative Energy Demand (CED) non-renewable, 1000 kg tissue paper, base scenarios**




Source: (Own depiction 2021, ifeu)

**Figure 22: Climate Change, 1000 kg tissue paper, base scenarios**




Source: (Own depiction 2021, ifeu)

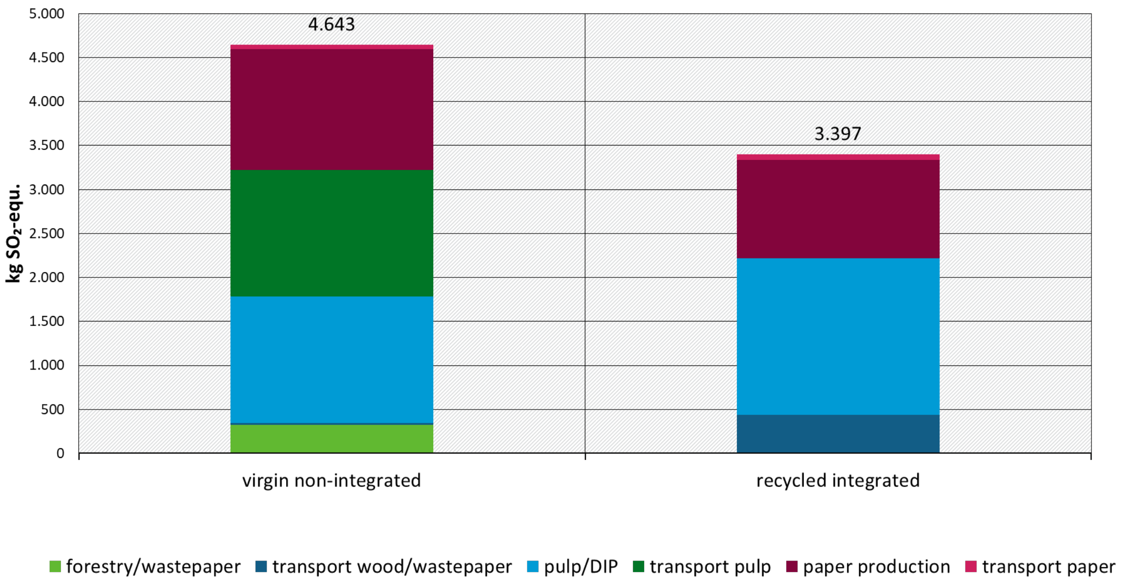
### 2.2.1.2 Tissue paper base scenario results: Acidification & Terrestrial Eutrophication

In this section, the environmental indicators related to non-carbon dioxide air emissions, but related to nitrogen and sulfur compounds, *Acidification* and *Terrestrial Eutrophication*, are considered. Those compounds are both typically associated with transports and combustion processes.

Recycled tissue papers are associated with at least 30 % to 60 % lower environmental impacts (Acidification and Terrestrial Eutrophication, respectively) than virgin tissue papers in the named indicators. For a good part, this is related to the pulping and pulp transport processes for virgin tissue papers, due to the release of sulfur and nitrogen content originating from biomass and the thermal nitrogen oxide generation during combustion.

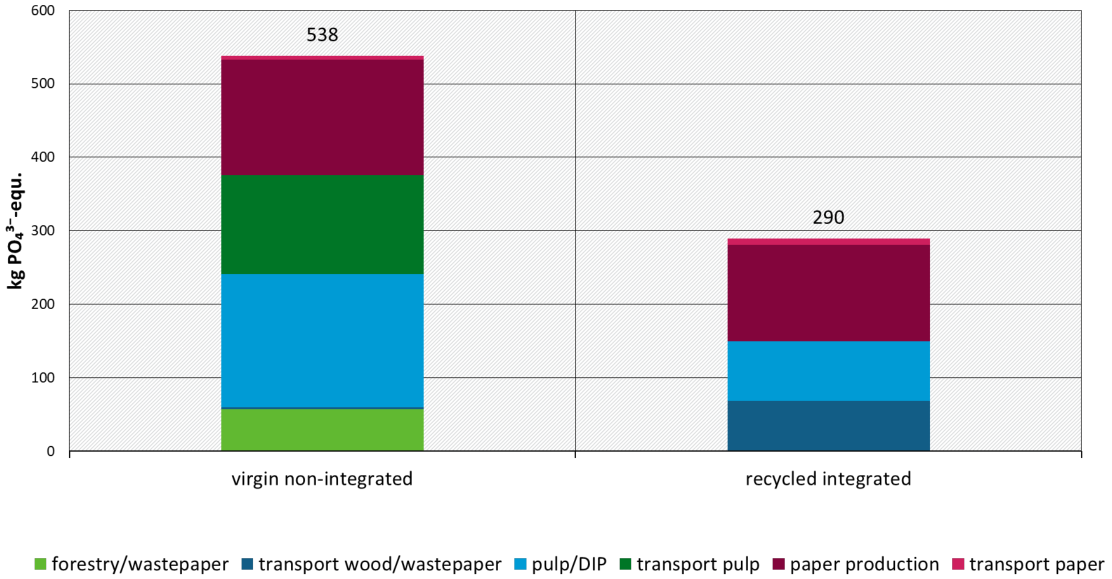
In case of non-integrated virgin tissue paper production, considerable transport processes contribute to both sulfur and nitrogen compounds emitted to air, due to pulp transports e.g. from Iberia and Latin America.

**Figure 23: Acidification, 1000 kg tissue paper, base scenarios**




Source: (Own depiction 2021, ifeu)

**Figure 24: Terrestrial Eutrophication, 1000 kg tissue paper, base scenarios**




Source: (Own depiction 2021, ifeu)

#### 2.2.1.3 Tissue paper base scenario results: Water-related results

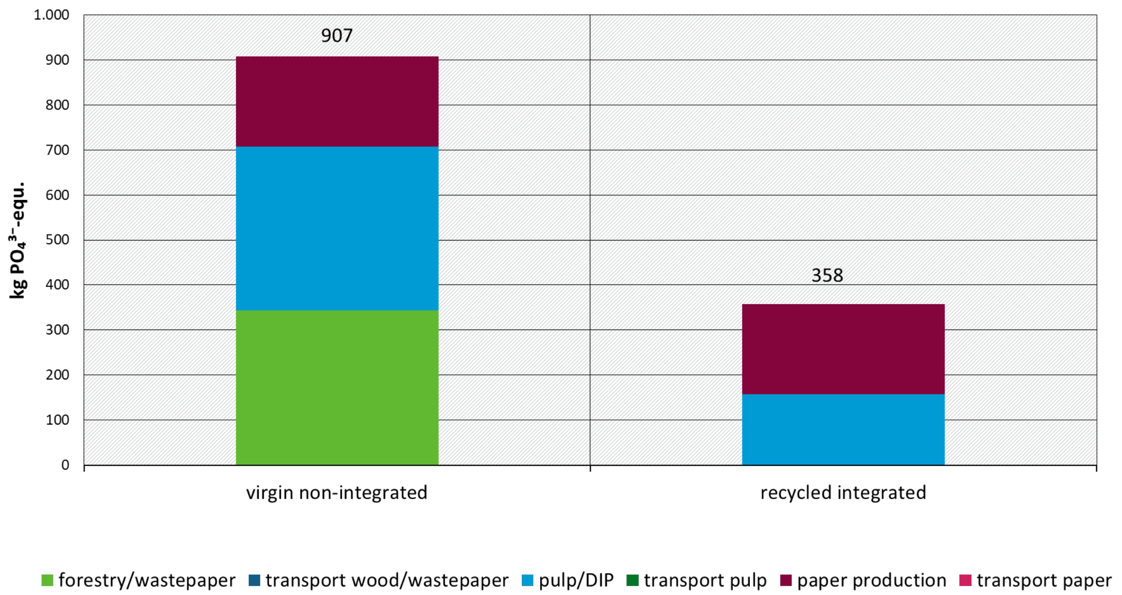
Looking at water-related environmental impacts and water-related environmental indicators provides additional insight into of the environmental performance of paper production. This includes *aquatic eutrophication*, *adsorbable organic halogenated compounds (AOX)*, and *process water demand (freshwater)*.

For the three environmental indicators in the focus here, recycled paper results are considerably lower (25 % lower in fresh water demand and at least 50 % lower or more in aquatic eutrophication) than the virgin paper counterpart examined.

As underlying emissions to water (such as COD) are largely related to the use of process chemicals, aquatic eutrophication related to overall paper production processes (i.e. integrated mill versus sum of pulping and papermaking in case of non-integrated production) is somewhat comparable per equal amount of virgin fibres. Furthermore, forestry does contribute as well due to nitrogen and phosphor compounds emitted to water, so virgin tissue paper is associated with some loads here as well.

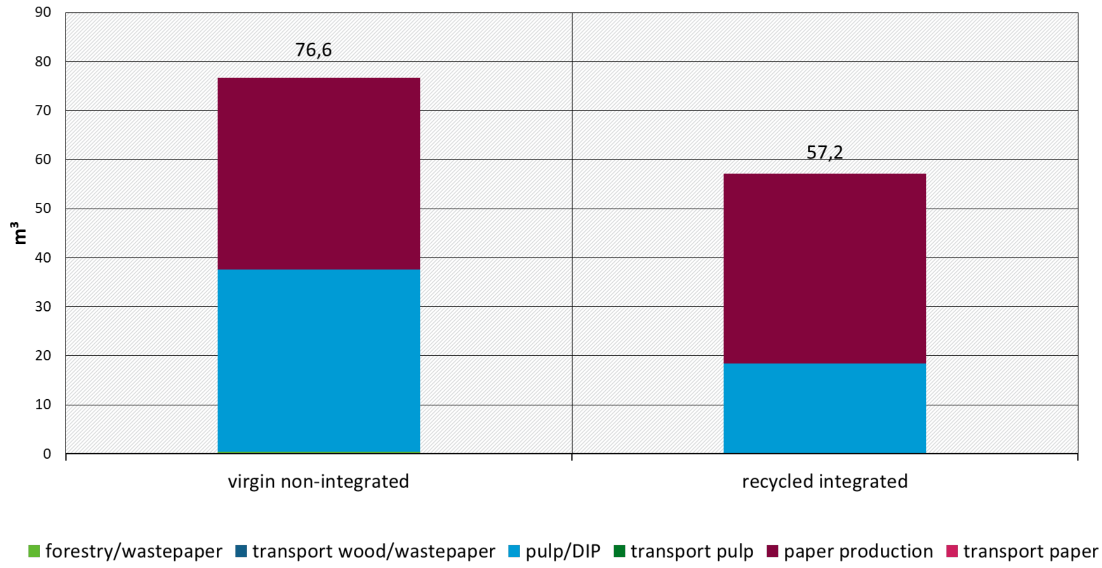
AOX emissions to water are directly related to the use of e.g. chlorine compounds in pulping processes, so here the share of TCF pulping is decisive for AOX emissions of virgin papers. As bleaching of DIP is typically carried out without halogen compounds, but e.g. using hydrogen peroxide and caustic soda instead, recycled tissue papers are associated with very small AOX emissions.

**Figure 25: Aquatic Eutrophication, 1000 kg tissue paper, base scenarios**



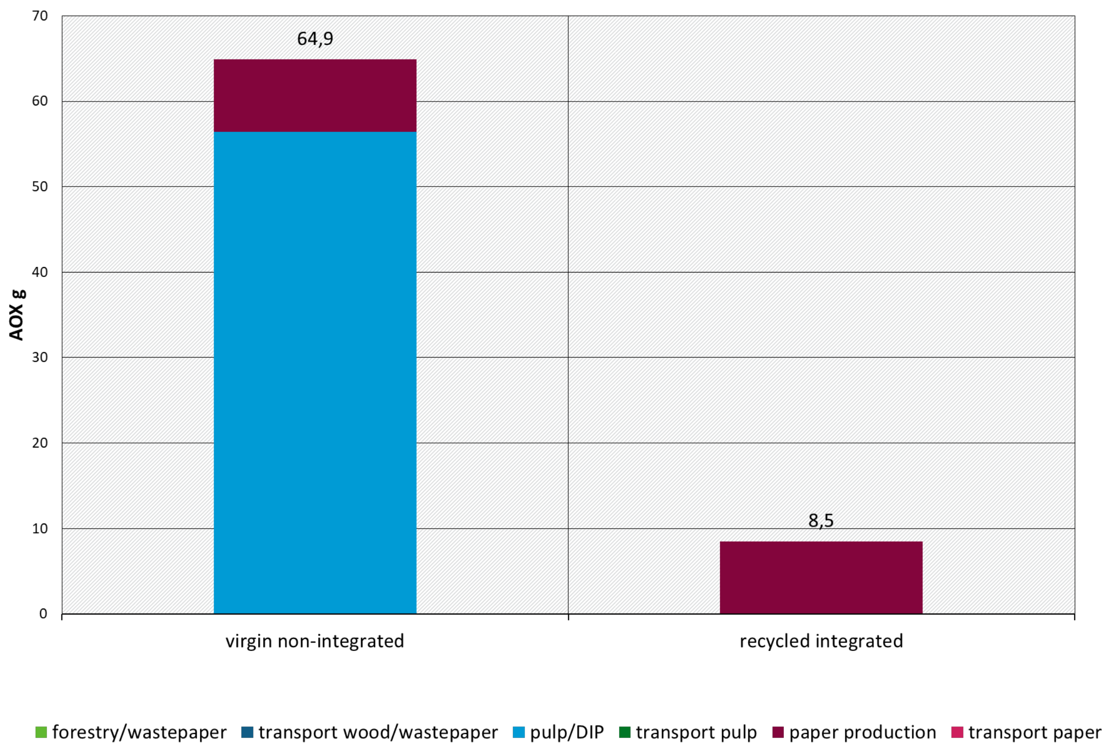

Source: (Own depiction 2021, ifeu)

**Figure 26: Freshwater Demand, 1000 kg tissue paper, base scenarios**




Source: (Own depiction 2021, ifeu)

**Figure 27: Adsorbable Organic Halogenated Compounds (AOX), 1000 kg tissue paper, base scenarios**




Source: (Own depiction 2021, ifeu)

#### 2.2.1.4 Tissue paper base scenario results: Human Health-related results

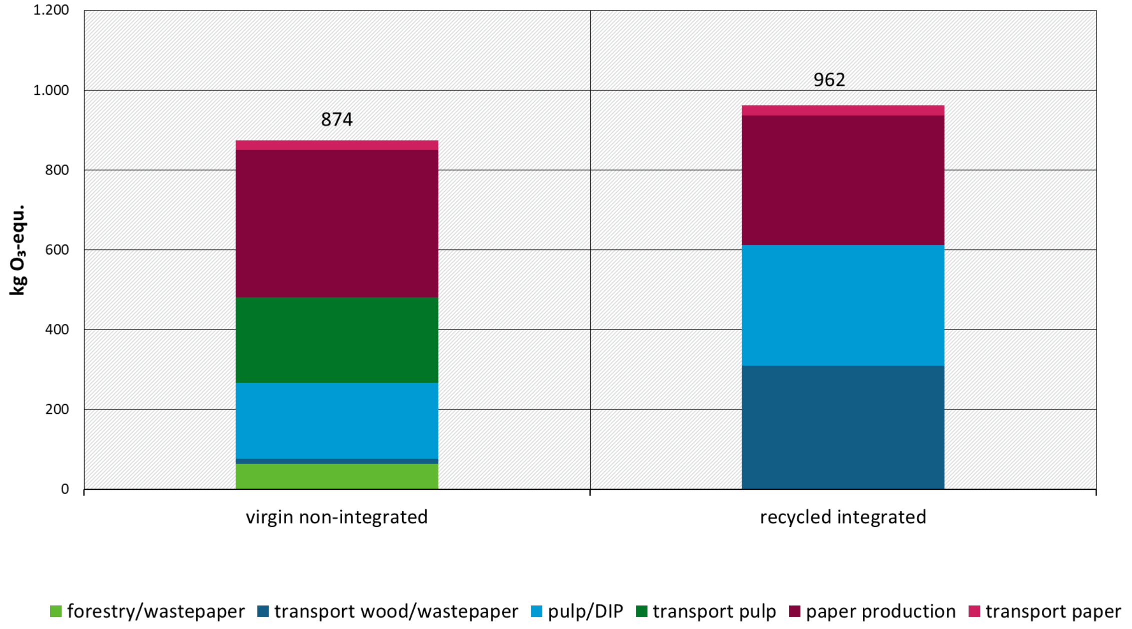
Environmental impact indicators *photochemical ozone formation* and *fine particulate matter (PM 2.5)* are environmental indicators that are also health-related. This section provides a closer look into the environmental performance of tissue papers regarding those aspects.

Virgin tissue papers are associated with comparable photochemical ozone formation than recycled papers. This finding is related to organic air emissions (VOC and NMVOC) associated with combustion processes / energy prechains in general. Some of those air emissions are also transport-related, thus besides the energy-intensive processing steps of pulping and papermaking, also wastepaper/pulp transports show contributions. Waste paper collection & transport is even associated with higher photochemical ozone formation than pulp imports in this case.

**However, comparative findings in this aspect have to be handled with care, as data symmetry within the various individual datasets contributing to this result may not be fully given based on the inventory data currently available.**

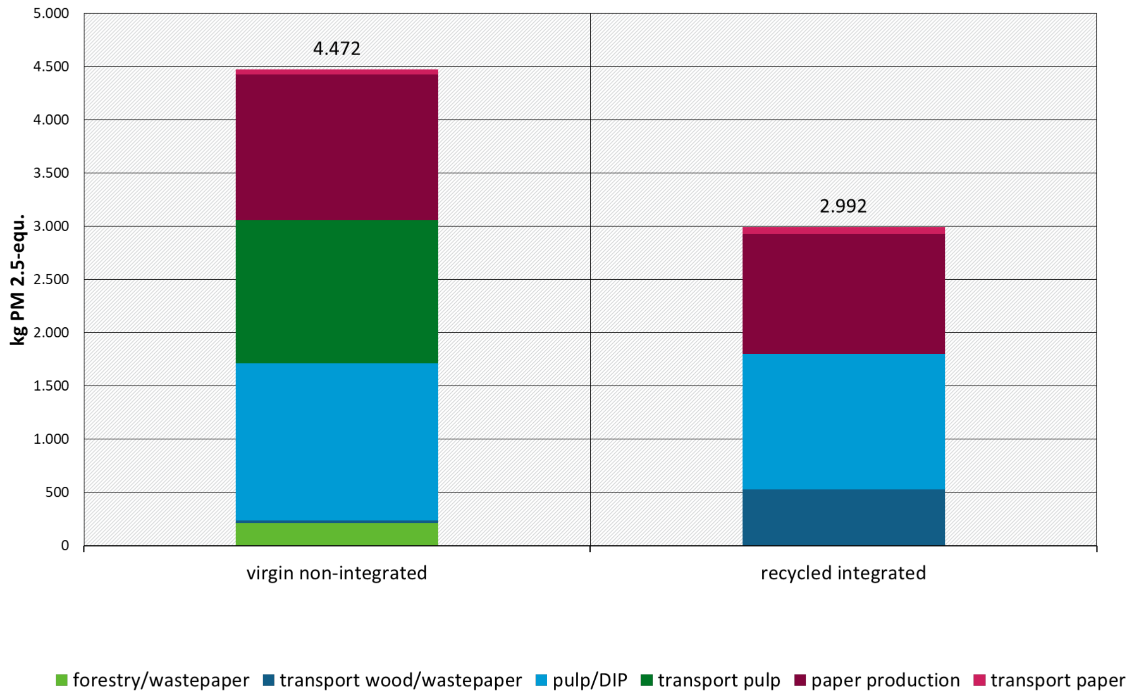
Recycled tissue papers on the other hand are associated with clearly lower fine particulate matter (PM 2.5) impacts than virgin tissue papers. This is for a good part related to secondary fine particles, such as nitrogen and sulphur oxides, originating from (also bio-based) energy generation in e.g. pulping processes.

**Figure 28: Photochemical Ozone Formation, 1000 kg tissue paper, base scenarios**




Source: (Own depiction 2021, ifeu)

**Figure 29: Particulate Matter (PM 2.5), 1000 kg tissue paper, base scenarios**



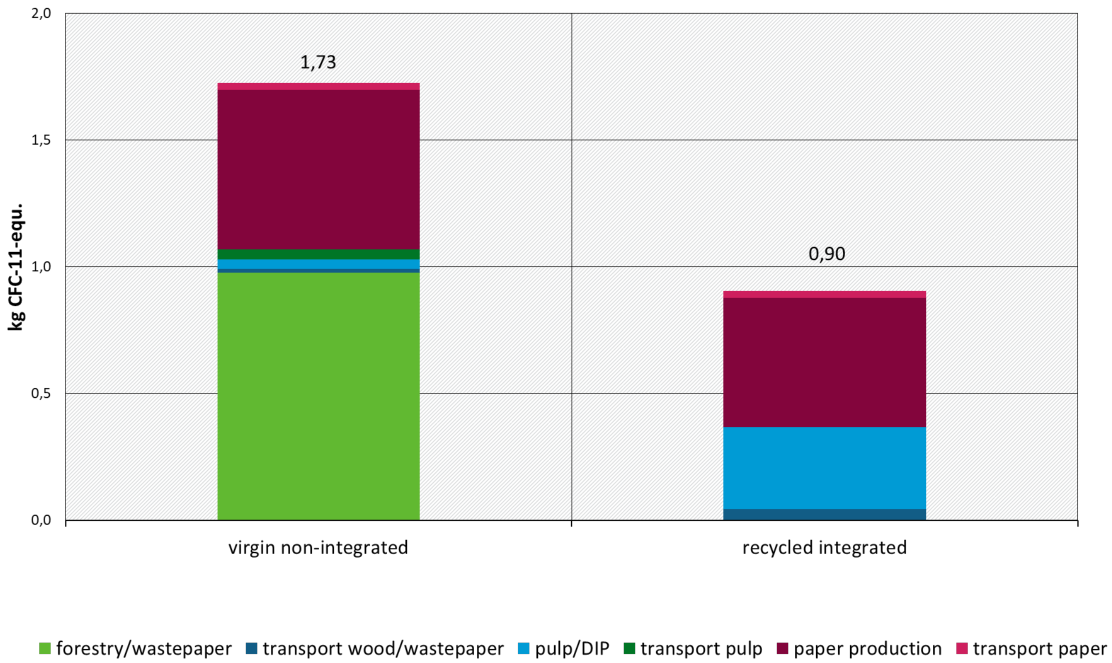

Source: (Own depiction 2021, ifeu)

#### 2.2.1.5 Tissue paper base scenario results: Ozone Depletion

Recycled tissue papers are associated with clearly lower ozone depletion impacts than virgin tissue papers examined. This is related to the emission of nitrous oxide (nitrous oxide, $N_2O$) to air as a result of forestry operations and thus contributing to ozone depletion more than 50 %.

Recycled tissue papers on the other hand show the highest contribution related to energy generation processes for papermaking, where also nitrous oxide is emitted as a result of combustion processes (both biogenic and fossil fuels) for the generation of heat e.g. for drying processes.

Figure 30: Ozone Depletion, 1000 kg tissue paper, base scenarios




Source: (Own depiction 2021, ifeu)

### 2.2.2 Further tissue paper variant scenario results

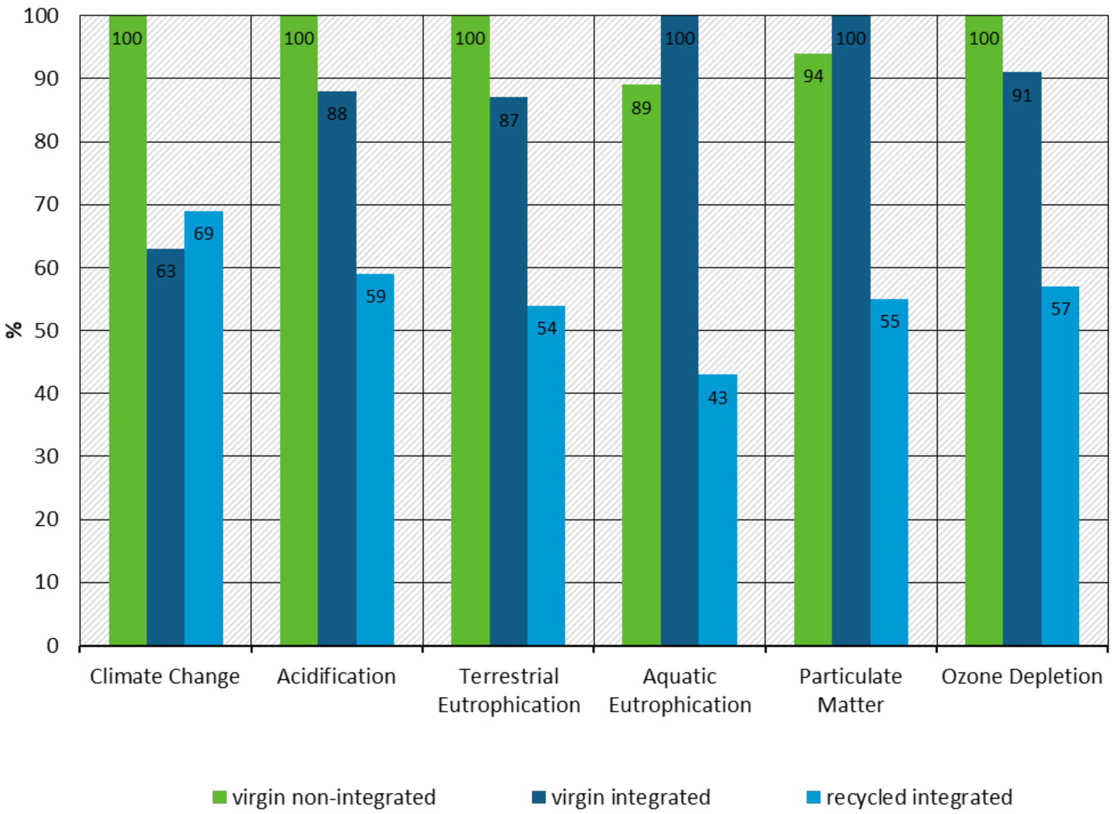
The results of further tissue paper variant scenarios are presented in the background report (UBA 2022) of this study.

## 2.3 Summary and discussion of LCA results

When assessing different production technologies for the production of office paper by comparing the *cradle-to-gate LCA results*, they show generally lower environmental impacts for the paper production from recycled paper. This is especially visible compared to a non-integrated production of paper from virgin fibres. The comparison of recycled office paper with virgin paper from integrated production shows lower impacts in the environmental impact categories Acidification, Terrestrial Eutrophication, Aquatic Eutrophication, Particulate Matter and Ozone Depletion, and similar impacts in the category climate change In the category photo-oxidant formation, the present study remains inconclusive due to a lack of comparable data (see section 2.1.1.4 on data asymmetry regarding photo-oxidant formation).

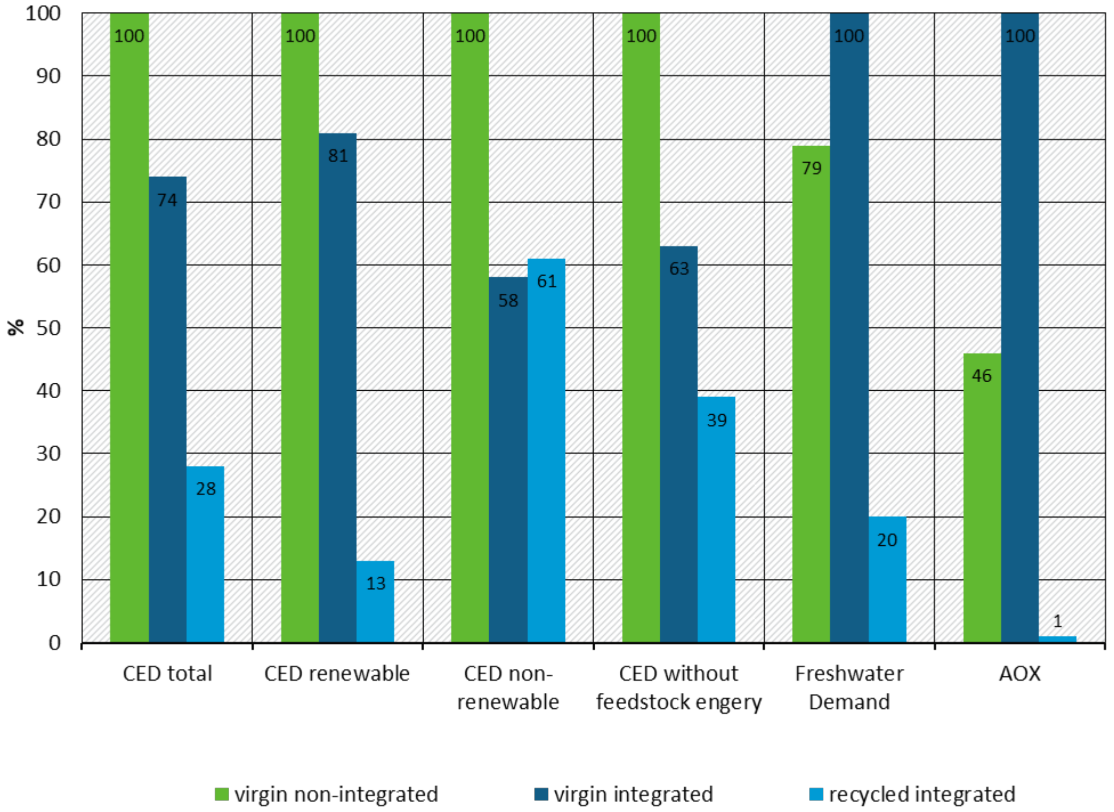
The following Figure 31and Figure 32 show the relative results of the environmental impact categories and the inventory categories for office paper.

Figure 31: Comparison of impact assessment results: virgin non-integrated and integrated produced office paper vs. recycled integrated produced office paper




Source: (Own depiction 2021, ifeu)

**Figure 32: Comparison of inventory category results: virgin non-integrated and integrated produced office paper vs. recycled integrated produced office paper**

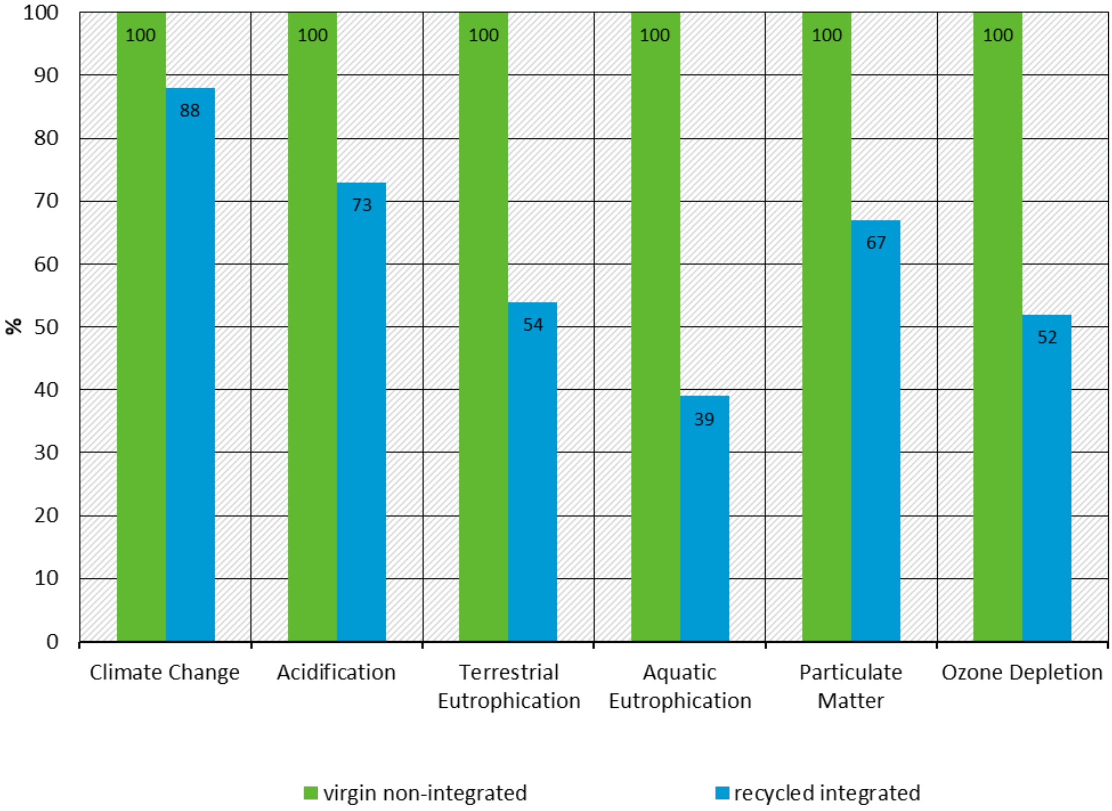



Source: (Own depiction 2021, ifeu)

When assessing different production technologies for the production of tissue paper by comparing the *cradle-to-gate LCA results*, they show lower environmental impacts for the paper production from recycled paper in all successfully assessed environmental impact categories.

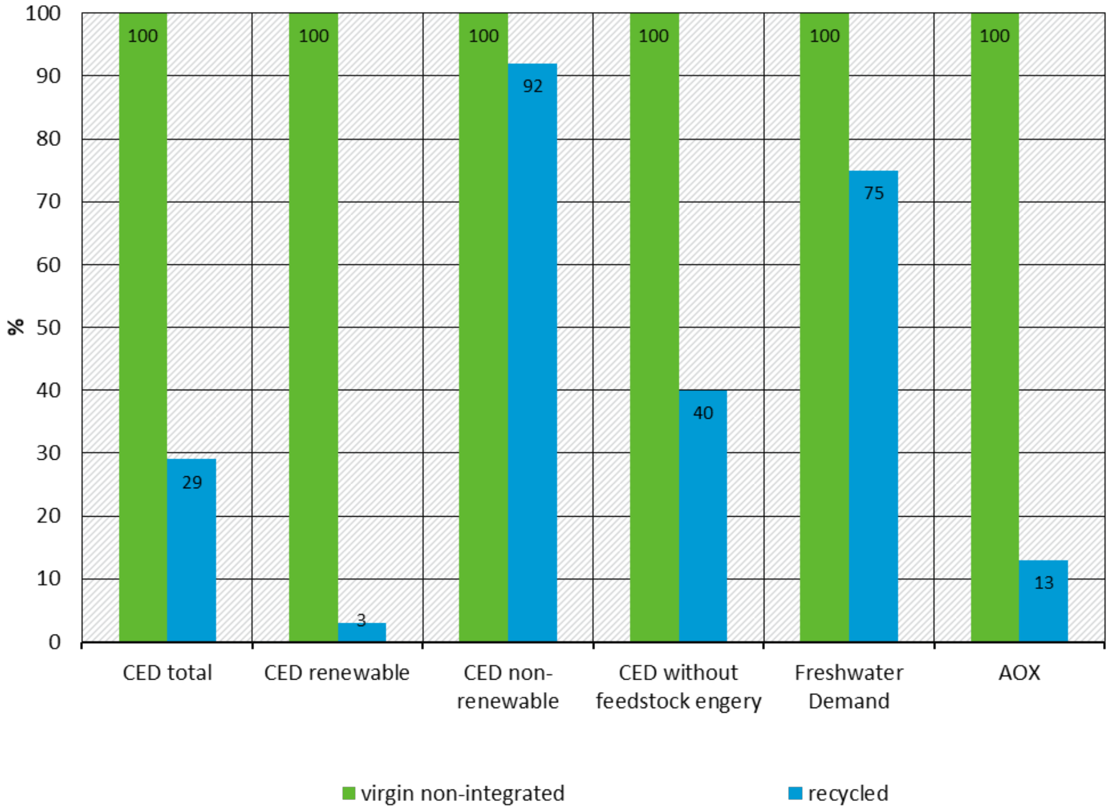
The following Figure 33 and Figure 34 show the relative results of the environmental impact and inventory categories for tissue paper.

**Figure 33: Comparison of impact assessment results: virgin non-integrated produced tissue paper vs. recycled integrated produced tissue paper**




Source: (Own depiction 2021, ifeu)

**Figure 34: Comparison of inventory category results: virgin non-integrated produced tissue paper vs. recycled integrated produced tissue paper**




Source: (Own depiction 2021, ifeu)

The results of the life cycle assessment show that recycled paper from integrated production generally performs better than the virgin papers compared. Especially in the comparison of recycled office paper from integrated production with virgin office paper from non-integrated production, the results of the recycled paper are substantially lower in all assessed environmental impact categories.

Compared to virgin office paper from integrated production, the recycled paper shows lower impacts in the assessed environmental impact categories Acidification, Terrestrial Eutrophication, Aquatic Eutrophication, Particulate Matter and Ozone Depletion. It shows similar impacts in the category Climate Change.

The comparison presented in section 2.1.2, in which both production types for virgin office paper are shown together as a weighted average, shows that when comparing recycled office paper against the average virgin office paper, the recycled paper also shows lower impact and inventory results than the virgin paper in all examined categories including Climate Change (15% lower impacts).

The sensitivity analysis presented in section 2.1.3 shows that the recycled paper production with a potential future electricity production mix with higher shares of renewable energy sources will lead to lower impacts. Also, the decarbonisation of the production of process heat in the coming years will further improve the results of recycled paper for the impact category Climate Change.

The comparison of recycled tissue paper from integrated production with virgin tissue paper from non-integrated production shows lower impacts in all successfully assessed environmental impact categories, including Climate Change.

# 3 Ecological assessment of wood origins

This section addresses land use criteria that are difficult to quantify, such as biodiversity, land use change and carbon storage in forests. The aim is to discuss these aspects, which go beyond LCA, and to draw conclusions regarding the use of virgin fibres in office and tissue paper, which in the synopsis complement the LCA results and contribute to an overarching view of the comparison of the papers examined in this study. For this purpose, the context of the international and national natural state of forests in relation to the demand for wood is first presented. For the subsequent consideration of biodiversity, land use change and $CO_2$ storage, the next subsection will show the wood origin for the scenarios used in the LCA. In addition, the significance of forest sustainability certification systems in relation to biodiversity and land use change is presented separately in the respective subsection.

Even though the analyses and assessments of the origin of wood for virgin fibre production presented here do not include the production of recycled fibres, the potential positive impacts of using recycled fibres instead of virgin fibres are addressed in the discussions.

## 3.1 Current debate on the natural state of forests

The status report "The State of the World's Forests" published by (FAO and UNEP 2020) shows that the world's forests provide extremely diverse habitats in which most terrestrial biodiversity can be found. Although the net loss of forest area has decreased, deforestation and degradation of forests associated with agriculture and pasture continues. Primary forests, which play an important role as carbon stores and for biodiversity, are also still under threat (FAO and UNEP 2020). The report highlights that the biodiversity targets of the Sustainable Development Goals for 2030 are unlikely to be met due to exploitative forest management and deforestation. This trend can be reversed by large-scale reforestation and sustainable forest management with a focus on biodiversity conservation (FAO and UNEP 2020).

The current report on the state of nature in Germany by the (BMU 2020) states that "efforts for ecological forest conversion, also in light of climate change, must be significantly intensified" and that forestry should be more strongly guided by "ecosystem aspects" (BMU 2020). This is also evident, among other things, in the implementation of the goals of the National Strategy on Biological Diversity. For example, the goal of the National Strategy on Biological Diversity, which is to permit unregulated forest development for 5 % of forested areas, has not been achieved as of 2019 (BMU 2020).

(BMEL 2014) provides an assessment of the forest condition based on the German Natural Forest Inventory and states in the preface that the forest is in good condition. The results in (BMEL 2014) show that 15 % of the forests have an almost natural, 21 % a semi-natural and 41 % a partly semi-natural composition of tree species. This remaining 23 % can be classified as accentuated by culture and conditioned by culture. It should be noted, however, that the parameter "naturalness" in the German National Forest Inventory refers exclusively to the tree species of the forest. Although the German Natural Forest Inventory may be considered advanced compared to other European countries, e.g. in the reporting of dead wood, tree species distribution or microhabitats on trees, "conclusions on the influence of forest management on the condition and changes in forest biodiversity are only possible to a limited extent" (Reise et al. 2017a). Accordingly, no conclusions on the natural condition or biodiversity of the forest can be drawn on the basis of the National Forest Inventory.

In contrast, the alternative forest condition report of the Naturwaldakademie Lübeck (Welle et al. 2018), shows an more comprehensive naturalness assessment of German forests according to the criteria of representation, vulnerability and rarity, closeness to nature, habitat tradition, conservation status and management. The aggregated result for the six criteria shows that more than 80 % of German forests are in a poor to very poor nature conservation condition.

The extent to which more sustainable forest management could be realised depends on the potential supply and demand for raw wood. For this purpose, various scenarios of the German wood market and its development up to the year 2050 were modelled in the project "Assessment of the sustainability of different forest management and timber use scenarios, with a focus on climate protection and biodiversity conservation" (WEHAM-Scenarios)[1]" funded by the Federal Ministry of Food and Agriculture (BMEL) and the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). In the WEHAM-scenarios presented e.g. by (Schier and Weimar 2018), different approaches to forestry are compared: a basic scenario based on current forestry practices, a timber preference scenario characterised by intensified forest management and a forest vision scenario with focus on nature conservation. The scenarios were combined with various wood demand scenarios: the basic scenario with the wood reference scenario (increase in wood for material use, decrease in wood for energy use), the wood scenario with the wood promotion scenario (increase in wood for material and energy use) and the forest vision scenario with the wood restriction scenario (slight increase in wood for material use and significant decrease in wood for energy use).

The results of all scenarios show that the demand for softwood for material use could be covered with domestic wood within the next few years if no wood is used for energy purposes. In the long-term perspective from 2030 onwards, however, the demand for softwood for material use would exceed the potential supply of raw softwood from German forests in every scenario examined (Schier and Weimar 2018). The demand for hardwood for material use could be covered by domestic wood in all scenarios until 2050, if no wood is used for energy purposes. This would also apply if the forest vision scenario were combined with scenarios that assume an increasing demand for hardwood for material use. If the Forest Vision scenario for softwood production is combined with scenarios that assume higher demand for softwood, the difference between demand and production would increase even more in the future. The difference between demand and domestic raw softwood supply will be covered by raw wood imports. Accordingly, a strong increase in demand for wood, especially coniferous wood, is in direct competition with the improvement of the state of nature and the conservation of biodiversity in the German forest or causes wood imports, which can also be associated with biodiversity losses or land use changes.

In addition to the loss of natural condition and biodiversity in forests, deforestation and forest degradation are also occurring on a large scale worldwide. While the net forest area is slightly increasing in Europe, a strong decrease is taking place especially in South America and Africa (FAO 2020). Since the net change in forest area equals the sum of changes due to deforestation and forest expansion (FAO 2020), the loss of primary forest in all regions may be higher than indicated by the statistics of net change in forest area. The main drivers of deforestation and degradation of primary forests are agricultural products (Cuypers et al. 2013, FAO and UNEP 2020). However, forest area losses are also associated with wood pulp imports, amounting to 0,1 million hectares for the years 1990 to 2008 (Cuypers et al. 2013). Approximately two thirds of this imported deforestation associated with wood pulp takes place in South America, the remainder in South East Asia and sub-Saharan Africa (Cuypers et al. 2013). In terms of net forest area in European countries, it can be seen that while the net forest area in Europe is increasing,

[1] German: „Nachhaltigkeitsbewertung alternativer Waldbehandlungs- und Holzverwendungsszenarien unter besonderer Berücksichtigung von Klima- und Biodiversitätsschutz (WEHAM-Szenarien)

the annual harvested forest biomass has increased significantly in recent years (Ceccherini et al. 2020). This shows that timber extraction and pressure on managed forests is increasing. In (Ceccherini et al. 2020), three possible causes for the recent increase in harvested area were investigated: 1) ageing of European forests, 2) increase in salvage logging, 3) market demand and policy framework, with the latter factor most likely being the most important driver for the increase in harvested area.

Therefore, based on the origin of wood for German paper production, the results of the biodiversity assessment for the scenarios presented in this report are presented below and possible risks related to land use changes as well as carbon loss in forests are discussed.

## 3.2 Wood origins for the German virgin fibre paper production

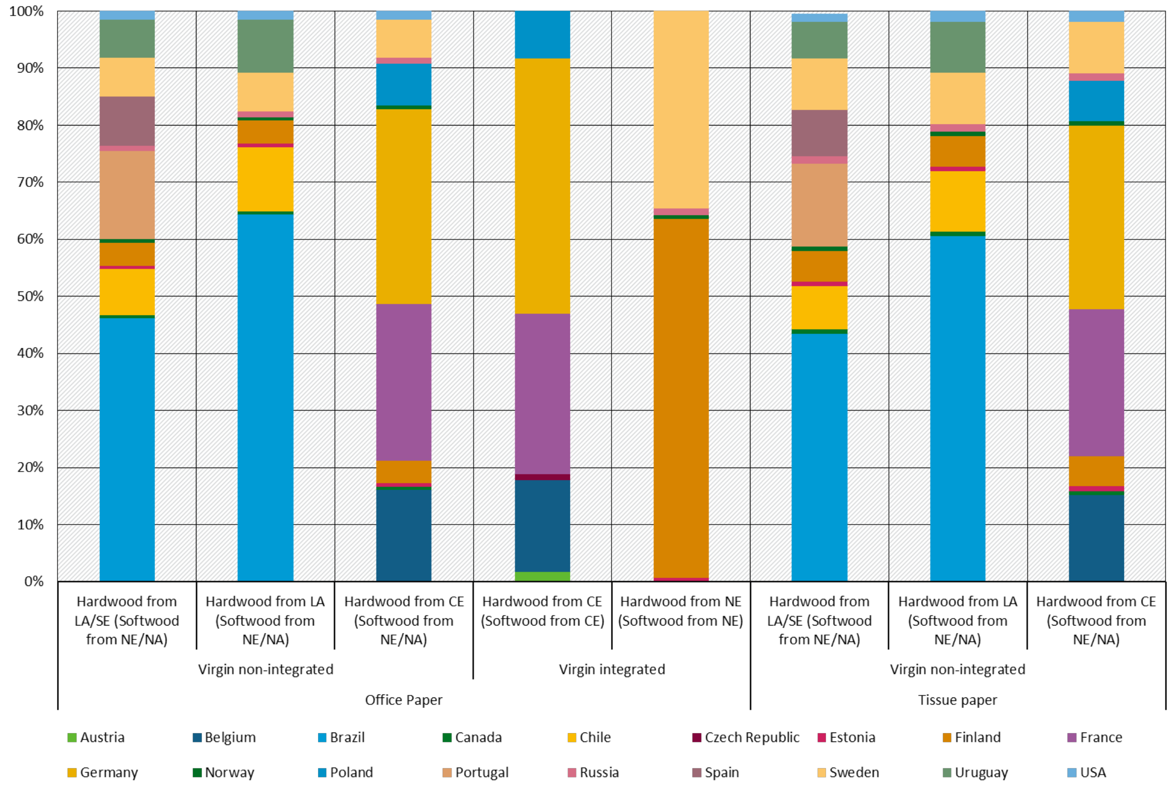
The assessment of natural areas and biodiversity in life cycle assessments and the analysis of potential land use change are based on the main countries of origin for the processed wood. The following list shows the scenarios selected for the ecological assessment of wood origins and their correspondences to the scenario names in the background report (UBA 2022). The scenario selection includes all important origin clusters of German paper production.

**Table 5: Correspondences of the scenario names for the ecological assessment of wood origins (LA = Latin America, SE = Southern Europe, NE = Northern Europe, NA = North America, CE = Central Europe)**

| Scenarios analysed for the ecological assessment of wood origins in the spotlight report. | | Corresponding paper base scenarios as well as the pulp type variant scenarios defined in sections 2.4.6 and 2.4.7. (Table 6 and 7) in the background report (UBA 2022). |
|---|---|---|
| **Office Paper: virgin non-integrated** | Hardwood from LA/SE (Softwood from NE/NA) | O1 virg. non-int. CE: [85 % Euca LA/SE, 15 % softwood NE/NA] |
| | Hardwood from LA (Softwood from NE/NA) | O1 virg. non-int. CE: [85 % Euca LA, 15 % softwood NE/NA] |
| | Hardwood from CE (Softwood from NE/NA) | O1 virg. non-int. CE: [85 % hardwood CE, 15 % softwood NE/NA] |
| **Office Paper: virgin integrated** | Hardwood from CE (Softwood from CE) | O2a virg. non-int. CE [85 % hardwood CE, 15 % softwood CE] |
| | Hardwood from NE (Softwood from NE) | O2b virg. int. NE [85 % hardwood NE, 15 % softwood NE] |
| **Tissue Paper: virgin non-integrated** | Hardwood from LA/SE (Softwood from NE/NA) | T1 virg. non-int.: [80 % Euca LA, 20 % softwood NE/NA] |
| | Hardwood from LA (Softwood from NE/NA) | T1 virg. non-int.: [80 % Euca LA/SE, 20 % softwood NE/NA] |
| | Hardwood from CE (Softwood from NE/NA) | T1 virg. non-int.: [80 % hardwood CE, 20 % softwood NE/NA] |

Figure 355 shows that the main countries of origin of wood used for paper production in Germany are very diverse, i.e. wood is imported from around the globe, e.g. from Brazil, Uruguay, Canada and USA, Spain, the Baltic States or Russia. The wood origin analysis is based on current wood production and import statistics based on the years 2016, 2017 or 2018. As far as the wood market figures allow a differentiation into sawn timber, industrial timber or pulpwood, the shares derived are based on the quantities supplied for paper or pulp production (see identifiers (a) to (d) Figure 355).

**Figure 35: Country of origin shares for hardwood and softwood per scenario for virgin non-integrated office and tissue paper and virgin integrated office paper (LA = Latin America, SE = Southern Europe, NE = Northern Europe, NA = North America, CE = Central Europe)**




Source: (Own depiction 2021, ifeu, based on:

Origin of pulp and paper for integrated- and non-integrated paper production based on (Moldenhauer et al. 2018)

Origin of hardwood and softwood estimates based on following sources:

**Finland (a)**: Luke (2020), reference year: 2019

**Sweden (b)**: SFIF (2020), reference year: 2018; Palviainen et al. (2015); Skogsstyrelsen (2019), reference year: 2018; EOS (2019), reference year: 2017; Ekstrom (2018), reference year: 2018; Generandi 2016, reference year: 2016

**Germany (c):** EOS 2019, reference year: 2017; BMEL (2018), reference year: 2018

**Austria (d)**: BMLRT (2017), reference year: 2016 and 2017; FAO and UNECE 2019, reference year: 2018, Höher and Strimitzer (2018), reference year: 2017

**France (b):** EOS 2019, reference year: 2017; UN 2019, reference year: 2017; Sédillot (2018), reference year: 2018; EOS and ETTF (2017), reference year: 2016

**(a)** wood imports and import countries based on pulpwood; **(b)** wood imports based on pulpwood, import countries based on industrial wood; **(c)** wood imports based on pulpwood, import countries based on raw wood; **(d)** wood imports and import countries based on industry wood

Most of the hardwood used in pulp and paper production is sourced in the pulp and paper producing countries, and only small quantities are imported. As with hardwood supplies, the softwood market in North America is mostly supplied from domestic stocks. Therefore, no imports to these countries are assumed.

In contrast, there are considerable market flows for softwood used for paper production in European countries. In Finland, for example, in addition to domestic pulpwood (28,4 million $m^3$), softwood from Russia (about 4,9 million $m^3$) and the Baltic States (about 2,4 million $m^3$) is used in paper production (Luke 2020), and Sweden imports wood from Finland, Norway and the

Baltic States. In 2018, Germany imported mainly industrial timber from the Czech Republic and Poland. The Czech Republic is also one of the main suppliers of softwood for Austria, whose wood for paper production also comes from Germany. France in turn imported small quantities of softwood from Germany and Finland.

The wood market is subject to constant change. In 2018, for example, German log imports from Norway and Estonia fell considerably in comparison to the previous year, while delivery volumes from Poland and the Czech Republic rose to around 2/3 of imports. These fluctuations in the wood market are not reflected in the data used here, as only annual statistics were used for the individual countries. However, this is considered sufficient as a basis for the analysis of forest areas.

## 3.3 Biodiversity assessment

Gradual differences between different types of not highly intensified forest management in different regions of the world are difficult to determine. A promising approach that at least allow a distinction between highly intensive and less intensive types of management at the country level can be found in the method of (Chaudhary and Brooks 2018). Therefore, the quantitative assessment of temporary land use in the context of this research project is carried out applying the biodiversity damage potential of (Chaudhary and Brooks 2018).

### 3.3.1 Methodology of the biodiversity damage potential of (Chaudhary and Brooks 2018)

In order to assess the impact of land use on biodiversity in the context of product life cycles, characterisation factors were developed in (Chaudhary and Brooks 2018), using the potential for biodiversity damage as an indicator. The biodiversity damage potential is expressed in potentially disappeared fraction (PDF) per $m^2$. This metric accounts for a fraction of species loss per ecoregion or country that may be potentially lost due to the human interaction on one $m^2$.

The potentially disappeared fraction for the 5 different land use types managed forests, plantations, pasture, cropland and urban was calculated in (Chaudhary and Brooks 2018) based on studies of the impact of land use on biodiversity for five species groups (mammals, birds, amphibians, reptiles and plants) for 804 terrestrial ecoregions. For each land use type, 3 different management intensities are addressed. For wood production, a distinction was made between the following land use types and management intensities:

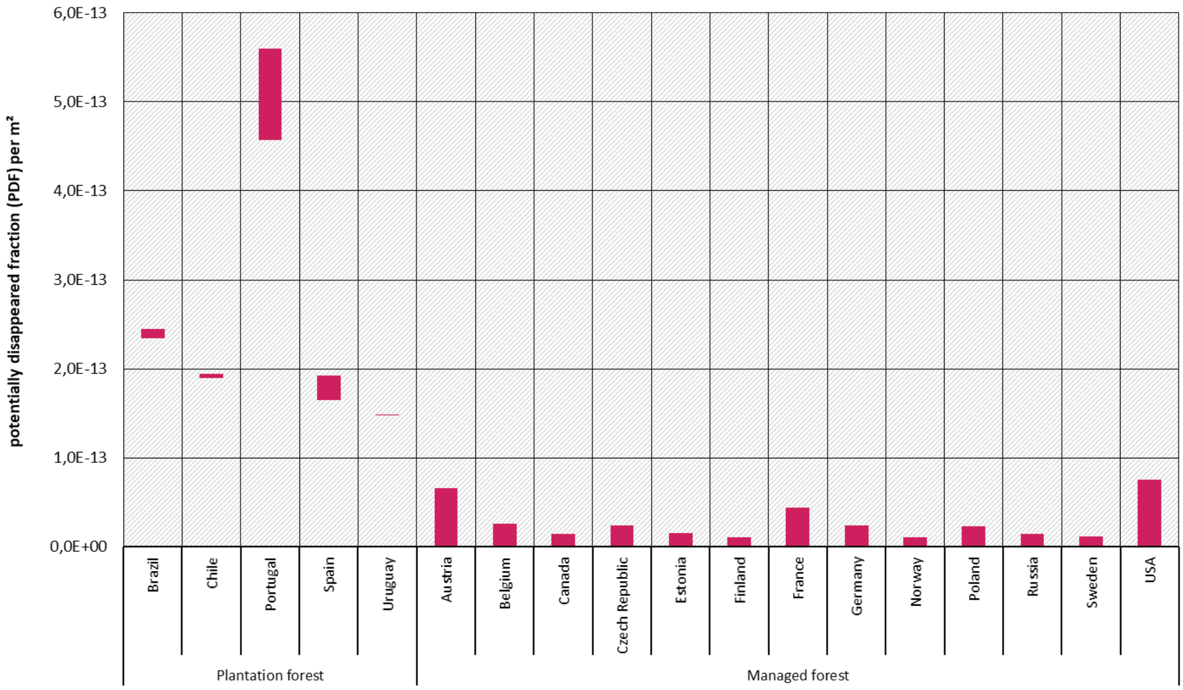
- Managed forests:
  - Intense use (Clear-cut/ final cut forests)
  - Light use (Selectively logged forests)
  - Minimal use (Reduced impact logging (RIL) forests)
- Plantation forests:
  - Intense use (monoculture plantations, similar aged trees, clear-felling within the last 20 years)
  - Light use (monoculture plantations, mixed age, no clear-felling in the last 20 years)
  - Minimal use (extensively managed or mixed timber plantations, no clear-felling in the last 20 years).

The characterisation factors of forest ecosystems are based on the meta-analysis published by (Chaudhary et al. 2016), in which 287 studies were used to compare biodiversity in managed and unmanaged forests. This meta-analysis showed that highly intensive clear-cutting leads to biodiversity loss in all taxa. Moreover, the potential biodiversity damage was higher in Central European forests than in Northern European forests. In contrast, the meta-analysis indicated that selective logging is not associated with any significant biodiversity damage in Central Europe and Scandinavia. For this reason, a characterisation factor of 0 PDF per $m^2$ (Potentially Disappeared Fraction) is reported in (Chaudhary and Brooks 2018) for these countries. This assumption is consistent with the results from (Reise et al. 2017a) and (Reise et al. 2017b) and reflects the current state of science. Using the method of (Chaudhary and Brooks 2018), significant differences between forest plantations, intensive forestry and less intensive forestry in different countries can be quantified. The limitation of the method is that a further nuanced differentiation of less intensive forms of management such as near-natural forestry is not yet possible. (Chaudhary and Brooks 2018) discuss the uncertainties of their method for the calculation of regional resolved potential biodiversity damage associated with a specific land use and management type. They conclude that these effects may be explained with data gaps, model and parameter uncertainties and the value choices inherent in the characterisation approaches.

Figure 366 shows the range of characterisation factors from low to high management intensity published by (Chaudhary and Brooks 2018) for the countries of origin attributed to German paper production. The flowing bars are to be understood as a range, with the lower edge of the bar representing the PDF for low and the upper edge representing the PDF for high land use management intensity.

In a country comparison, the factors can be interpreted as follows: the land occupation impact per hectare is 5,5 times higher if clear-cutting (high management intensity) takes place in Austria compared to Sweden or that the potential biodiversity impact per hectare of forest plantations in Portugal is about 2 to 4 times higher than in the other countries. The higher values and wider range of values of Portugal compared to the other countries come from plantation forestry in Madeira, where the potential biodiversity loss of the 'Madeira evergreen forest' ecoregion has a high vulnerability and sensitivity to the intensity of plantation management. The characterisation factors presented are the basis of the biodiversity assessment and show differences in the potential impacts of forestry and plantation management per area. In order to calculate the biodiversity loss potential of products, this area-based value has to be multiplied by the plantation or forest area, which results from the area yield and the amount of wood used.

**Figure 36: Range of characterization factors from (Chaudhary and Brooks 2018) for forest plantation and managed forests countries of origin attributed to the German paper production in potentially disappeared fraction (PDF) per m²**




Source: (Own depiction 2021, ifeu)

### 3.3.2 Potential impact of forest certification system on biodiversity loss

The following paragraphs are intended to show the extent to which FSC- or PEFC-certified forest areas can be given preferential consideration in the biodiversity assessment.

A literature review on the influence of certification systems such as Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certification Schemes (PEFC) on forest biodiversity shows that there is little evidence of a significant positive effects of forest certification on biodiversity. This is outlined in (Kuijk et al. 2009) and (Di Girolami and Arts 2018). (Di Girolami and Arts 2018) provides a qualitative literature review of 31 studies on the environmental impacts of certification schemes, which account for about 1.5% of certified forests worldwide. This review covers six case areas with FSC and two with PEFC certification in boreal forests. Half of the studies showed that the certification schemes had no statistically significant impact, the other half showed a positive effect on fauna. For the tropical biome, only studies with FSC certificate have been identified to analyse the effect on flora and fauna. "For the tropical biome, FSC succeeds in halting or reducing deforestation in most reported cases" (Di Girolami and Arts 2018), however, these studies do not comprise FSC certified forest plantations in the wood origins that are addressed in the present study. All in all (Di Girolami and Arts 2018) showed that FSC and PEFC shows positive or neutral impacts on the fauna and flora and only one study provides evidence of some negative impact in the tropical biome.

Beside literature on the impact of forest certification systems, there is a large body of literature on the relationship between biodiversity and retention forestry that is part of certification schemes. Retention forestry focuses on continuity in the forest structure to promote biodiversity and maintain ecological functions at different spatial levels. To this end, wood harvesting leaves intact key structures such as living and dead trees and tree stumps, and allows undisturbed forest development in small patches.

Most European FSC and PEFC criteria catalogues contain criteria for measures that are key elements in retention forestry. Exceptions are the Czech Republic, where the FSC and PEFC criteria catalogue, and Russia where the PEFC criteria catalogue does not require quantifiable measures on retention management (FSC 2015; FSC 2020; PEFC 2015; PEFC 2016). The updated Russian FSC National Standard includes criteria for retention measures, but the guideline to leave belts and clumps of 10% of the harvested area only applies to clear-cut areas larger than 15 ha. However, the updated Russian FSC Standard still does not provide guidelines for reducing clear-cut size, as criticised in (Blumröder et al. 2020).

The available literature shows that retention forestry sustains forest properties and functions to a certain extent, maintain much biodiversity in commercial forests and, depending on the area retained, a loss of biodiversity is prevented in contrast to conventional clear-cutting (Gustafsson et al. 2010; Fedrowitz et al. 2014; Lundmark et al. 2017; Kruys et al. 2013; Simonsson et al. 2015; Tikkanen et al. 2006; Belyazid et al. 2013; Gustafsson et al. 2020). However, (Gustafsson et al. 2020) states also that "> 50% of stand volume needs to be retained in order to maintain common forest species, and retention patches need to be more than half a ha in size, and probably larger, to preserve old-forest species communities". In (Kuuluvainen et al. 2019) it is shown that the level of retention is relevant for maintaining biodiversity. The case study of Finland published by (Kuuluvainen et al. 2019) showed that the "retention levels in the Finnish PEFC certification scheme are far too low for significant positive biodiversity impact." How FSC-certified areas, where the diameter must be twice as large as under PEFC, would perform is not discussed in (Kuuluvainen et al. 2019). Further research is needed on retention approaches and how the currently applied land-specific retention criteria of FSC or PEFC maintain biodiversity compared to conventional clear-cutting in Northern Europe. It has to be noted, that retention measures can also be established on non-certified areas.

However, (Gustafsson et al. 2020) states that "even leaving small amounts is better than traditional clearcutting with removal of all trees". Therefore, for the following biodiversity assessment, the FSC- and PEFC-certified areas are used to create a "low" PDF scenario in which the certified area share is not counted as conventional clear-cutting, but as retention forestry.

### 3.3.3 Application of the biodiversity damage potential approach

The biodiversity damage potential approach is applied in three steps: first, the forest and plantation areas required for wood production are classified into the land use classes of (Chaudhary and Brooks 2018); second, the areas are assigned to management intensities according to the timber origin determined in Chapter 3.2 and based on this, scenarios are formed; and third, the results are calculated and presented.

#### 1. Classification into land use types

Within this study, the classification of forest land used for paper production into the two land use types managed forest and plantation forest listed in section 3.3.1, is based on the definitions of land use types described in (Chaudhary et al. 2016). Accordingly, eucalyptus wood is assigned to plantation forests and the remaining softwood and hardwood forests to managed forests.

#### 2a. Classification into management intensities: managed forests

The following shows which proportions of the wood from the countries considered in this study are assigned to the three intensity classes (intensive use, light use and minimum use plantation and commercial forest).

The softwood and hardwood forests of the Northern Hemisphere can be classified within the managed forest either as clear-cut or selectively logged forests. Since the Reduced Impact

Logging (RIL) as minimal use forestry is intended for tropical forests, this class is not considered for wood from Central and Northern Europe as well as Russia and North America (Chaudhary et al. 2016). Retention forestry in boreal and temperate regions as a form of clear-cutting, can be considered as light use forestry management according to (Chaudhary et al. 2016).

In the following, the proportion of clear-cut or selectively logged forests in the countries of the Northern Hemisphere is derived.

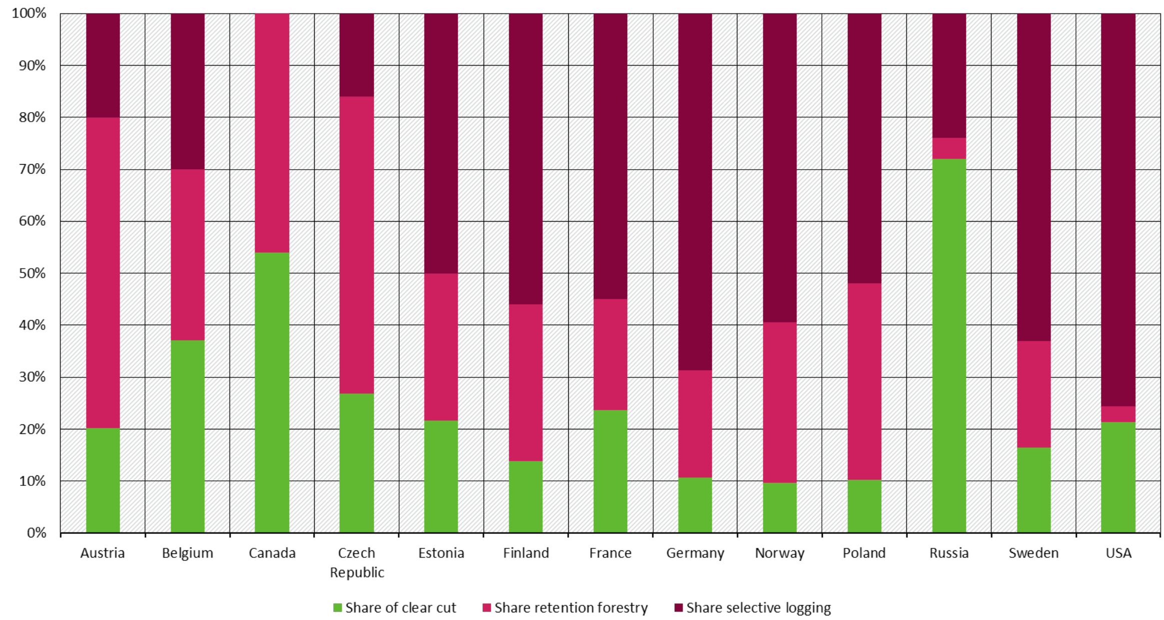
A recent study on the harvested forest area in the European Union was published by (Ceccherini et al. 2020) in July 2020. This study includes the proportion of wood harvested through clear-cutting in each EU country. These shares, which include shelter wood cutting and salvage logging and represent an average over several years, were used as the basis for the present biodiversity assessment for the EU countries. For Germany, an average clear-cutting percentage of 34 % of total felling was published in (Ceccherini et al. 2020) for the years 2000 to 2015, corresponding to the "harvest volume from final felling and salvage logging after major natural disturbances" (Ceccherini et al. 2020). As the present study refers to the German paper production, the share of harvest from salvage logging has been recalculated based on logging statistics of the years 2014 to 2019 (Destatis 2015; Destatis 2016; Destatis 2017; Destatis 2018; Destatis 2019; Destatis 2020). The average share of harvest from salvage logging of the years 2014 to 2019 amounts to 31 % of the total felling. The clear-cut shares for non-EU countries are based on the following most recent literature sources: Canada based on (NFD 2020) (average of the years 2017 and 2018), Norway calculated as average of Finland and Sweden, Russia based on (Prokopov 2007) (year 2003) and USA based on (USDA 2015; USDA 2016; USDA 2017; USDA 2018; USDA 2019) (average of the years 2015 to 2019).

From the perspective of biodiversity, salvage logging without retention of biological legacies is also associated with negative impacts (Thorn et al. 2018; Lindenmayer and Noss 2006; Orczewska et al. 2019). (Thorn et al. 2018) concludes that “salvage logging has a range of effects on species numbers and community composition of various taxonomic groups, with important negative consequences for several groups, especially saproxylic ones.” (Thorn et al. 2018) suggest that the impact of salvage logging on biodiversity would be reduced by “leaving substantial amounts of dead wood on site” (Thorn et al. 2018). Of course, salvage logging as unintentional harvest is not comparable to planned conventional clear-cutting in terms of the intensity of intervention and the frequency with which thinning and logging are carried out. However, since salvage logging without retention measures shows negative impacts on biodiversity, it is treated as clear-cutting in the following

The figures presented above on the amount of clear-cutting (incl. salvage logging) do not address the question whether retention forestry is practised. Due to a lack of information on actual forest management in the respective countries, the proportion of certified forest area is classified as retention forestry and thus treated as selectively logged forests. The following Figure 377 shows the share of clear-cut, retention forestry and selective logging that is used for the present biodiversity assessment.

Due to the uncertainty about the actual proportion of retention forestry and the effectiveness of retention forestry on maintaining biodiversity (see section 3.3.2), two scenarios were calculated: one in which retention forestry is classified as selective logging ("low"-PDF scenario) and one in which retention forestry is classified as clear-cutting ("high"-PDF scenario) within the framework of the method of (Chaudhary and Brooks 2018).

**Figure 37: Share of final cut, retention forestry and selective logging for countries of origin attributed to the German paper production**




Source: (Own depiction 2021, ifeu, based on (Ceccherini et al. 2020) for Austria, Czech Republic, Estonia, Finland, France, Poland and Sweden, (Destatis 2015; Destatis 2016; Destatis 2017; Destatis 2018; Destatis 2019; Destatis 2020) for Germany, (NFD 2020) for Canada, average of Finland and Sweden for Norway, (Prokopov 2007) for Russia and (USDA 2015; USDA 2016; USDA 2017; USDA 2018; USDA 2019) für USA)

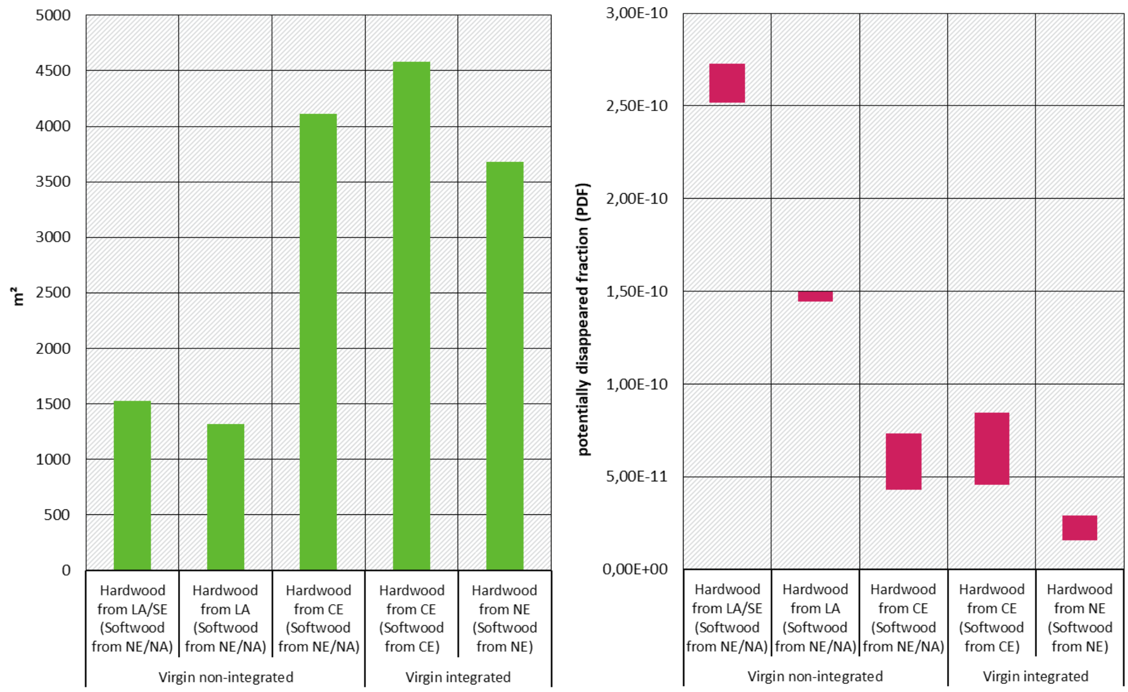
### 2b. Classification into management intensities: plantation forests

According to the definitions provided by (Chaudhary and Brooks 2018), eucalyptus wood from South Europe and South America is classified in the plantation forests subcategory Intense Use. To explore how a less intensified plantation management would influence the results, two scenarios are also drawn up here. The "high"-PDF scenario is based on the mentioned assumption that all plantations are classified as Intense Use. For the “low"-PDF scenario the plantations are classified as one level less intensive.

### 3. Calculation and presentation of biodiversity assessment results

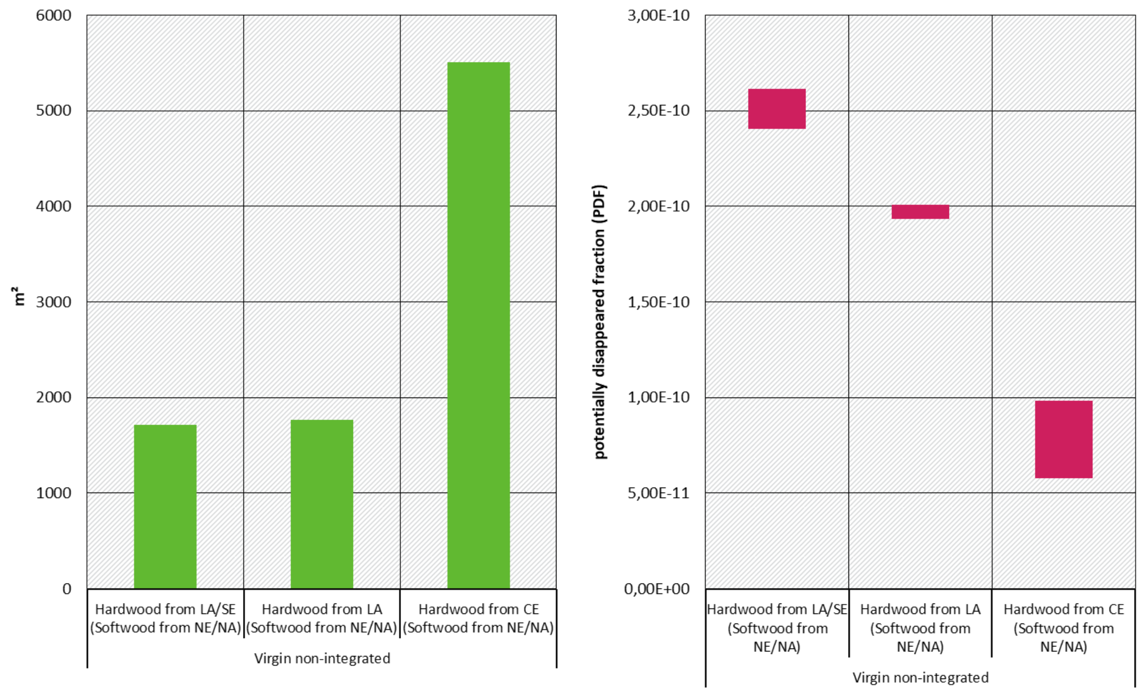
The biodiversity damage potential of the paper products is obtained by multiplying the forest areas quantified in the LCA (charts on the left in Figure 388 and Figure 399) by the characterization factors given for each country according to (Chaudhary and Brooks 2018). For the forests of the Northern Hemisphere, the forest area demand is first divided into intensively used and lightly used management and then multiplied by the respective characterisation factors. The “high”- and “low”-PDF scenarios differ in whether retention forestry is assigned to clear-cut or selective logging. For eucalyptus wood, the total area is multiplied by the intensive use factor for the “high”-PDF scenario and by the light use factor for the “low”-PDF scenario. Figure 388 and Figure 399 illustrate the results of the forest area demand alongside the biodiversity damage potential according to (Chaudhary and Brooks 2018) for 1000 kg of office and tissue paper. The flowing bars (charts on the right in Figure 388 and Figure 399) show the range of results for the PDF for the defined "low"- and "high"-PDF scenarios and therefore the influence of assumptions about the chosen management intensities (“low”- and “high”-PDF scenarios). The lower edge of the bar shows the PDF results for the “low”-PDF scenario and the upper edge for the “high”-PDF scenario for the procurement of wood per wood origin scenario as defined in section 3.2.

**Figure 38: Total forest area (left) and potentially disappeared fraction results shown as range for "low"- and "high"-PDF scenario variants (right), 1000 kg office paper (LA = Latin America, SE = Southern Europe, NE = Northern Europe, NA = North America, CE = Central Europe)**




Source: (Own depiction 2021, ifeu)

**Figure 39: Total forest area (left) and potentially disappeared fraction results shown as range for "low"- and "high"-PDF scenario variants (right), 1000 kg tissue paper (LA = Latin America, SE = Southern Europe, NE = Northern Europe, NA = North America, CE = Central Europe)**




Source: (Own depiction 2021, ifeu)

Land use at inventory level (total forest area, charts on the left in Figure 388 and Figure 399) shows lower results for the eucalyptus-based variants (hardwood from LA/SE or LA) than for the scenarios where the hardwood originates from Central or Northern Europe. However, taking into account the potential damage to biodiversity (charts on the right in Figure 388 and Figure 399), this outcome is reversed. The use of eucalyptus wood leads to potentially higher biodiversity damage than the use of hardwoods from Central or Northern Europe. In particular, the extraction of European eucalyptus wood leads to potentially higher biodiversity damage than the use of eucalyptus wood from South America. This may be explained firstly by the higher characterization factors of the Portuguese forest plantations (biodiversity damage potential per area) due to the higher potential for disappearance of endemic species of the 'Madeira evergreen forest' ecoregion. Secondly, the cultivation of eucalyptus wood in Portugal and Spain requires more area of forest land per cubic metre eucalyptus harvested due to a lower growth rate compared to South America.

It is important to note that the assumption that salvage logging has the same effect as planned conventional clearcutting may lead to an overestimation of impacts, as the unplanned use of fallen, broken and insect-infested wood is associated with a potentially lower intensity than planned clearcutting as a harvesting method.

### 3.3.4 Discussion of the biodiversity damage potential results

The range of the results show that different management types of plantations in Latin America do improve the result only slightly. In relation to the overall result, they have relatively little impact on the potential biodiversity damage associated with the production of eucalyptus wood. It should be noted that a plantation can only be classified as "light use" if no clearcutting has been carried out in the last 20 years. And even then, the potential for biodiversity loss is higher than in the scenarios where the hardwood comes from managed forests in Central and Northern Europe.

In managed forests of the Northern Hemisphere, the intensity of forestry has a strong influence on the results. The comparison of the potential biodiversity damage resulting from paper production using wood from Central European and Northern European forests is therefore strongly dependent on the proportion of highly intensive forest use. As the share of retention forestry in clear-cutting and the effectiveness of the actual implemented retention forestry management for biodiversity conservation is not known for European countries, the results for both Central European and Northern European countries may be over- or underestimated. Even though the characterization factors for Germany and France show a clearly higher potential for damage to biodiversity through intensive forestry than the Northern European countries, the uncertainties regarding classification into the forest management types have a greater impact. Furthermore, the total area attributed to clear-cutting in Germany comes from salvage logging, which may have a lower potential impact on biodiversity than planned clear-cutting; therefore, the results for paper with wood supply from Central Europe might be overestimated. Therefore, no comparative statements can be made at this point to distinguish the choice of wood origin from Central or Northern Europe.

**Summary: biodiversity assessment**

In general, any wood extraction for virgin fibres represents an intervention in forest ecosystems and thus carries a certain potential for damage to forest biodiversity. The use of recycled fibres, on the other hand, would reduce the potential for damage to forest biodiversity.

In case of wood extraction for virgin fibre production, the analysis of the areas using the method proposed by (Chaudhary and Brooks 2018) shows that despite the fact that more forest area is needed per same amount of paper (charts on the left in Figure 388 and Figure 399), softwood and hardwood from Central or Northern Europe used in virgin fibre paper production has a lower biodiversity damage potential (charts on the right in Figure 388 and Figure 399), than paper production from eucalyptus wood. Furthermore, it is evident that wood extraction for paper production from forest plantations in Portugal potentially leads to higher biodiversity damage than wood extraction from South America. Within European forest management, it is important to avoid conventional clear-cutting and to use less intensive forest management.

## 3.4 Land use change

On the basis of the available studies (FAO and UNEP 2020; Keenan et al. 2015), a potential risk regarding land use change from primary forest to commercial forest or forest plantations can be derived for the wood origins used for German paper production.

In the following, the risks of a change of land use from primary forest areas to commercial forests or forest plantations per region of the countries of origin are explored. For the purpose of this study, the term "primary forest" is used for forests having a high naturalness and therefore include primeval, virgin, old-growth, intact or long-untouched forests as in (Sabatini et al. 2018) and in accordance with (FAO 2015). Primary forests that are greater than 500 $km^2$ in extent and that are "large enough that all native biodiversity, including viable populations of wide-ranging species, could be maintained" (Potapov et al. 2008), have been mapped globally under the Intact Forest Landscapes (IFL) approach. Within the present study, all primary forests are considered regardless of extent.

Before that, it will also be shown whether a certification system for sustainable forestry can help to minimize the risk of land use changes.

### 3.4.1 Consideration of land use change in certification schemes for sustainable forests

► Plantation forests

The sustainable forest management certification system of FSC includes restrictions on the conversion of primary forests to forest plantations (FSC 2018a). It is stated that "management units containing plantations that were established on areas converted from natural forest after November 1994 shall not qualify for certification, except where: a) clear and sufficient evidence is provided that the Organization was not directly or indirectly responsible for the conversion, or b) The conversion affected a very limited portion of the area of the Management Unit and is producing clear, substantial, additional, secure long-term conservation benefits in the Management Unit". The limit for the very limited proportion is set to 5% of the management unit. This means that wood from FSC-certified forests or forest plantations excludes at least 95 % an intended conversion from primary forest to forest plantations after 1994. Forest plantations are defined among others as forest area "established by planting or sowing with using either alien or native species, often with one or few species, regular spacing and even ages, and which lacks most of the principal characteristics and key elements of natural forests" (FSC 2018a). Whether a managed boreal forest is classified as a plantation depends on the national FSC guidelines. It also has to be noted, that a policy draft (FSC-POL-01-007) on conversion aspects was developed by a sub-chamber balanced working group from 2017 to 2020. The third and fourth draft revision of this policy has been published in September 2020 and April 2021 (FSC 2020; FSC 2021). Under the present proposals, an area converted after November 1994 and before 'the effective date of the' policy will be eligible for FSC certification of forest management if the conversion is more than 5 years old and a defined remedy action is followed. Management Units that contain natural forest areas converted after the effective date of this policy would not be eligible for FSC certification (FSC 2021). Depending on how the policy of conversion is changed, the risk of land use change may increase for FSC land.

The PEFC standard, on the other hand, endorses only national standards that regulate forest conversion and "does not prohibit the conversion of natural forest to plantation, but stipulates that conversion should take place only under "justified circumstances"" (FAO 2018). Furthermore, "forest plantations from before 2011 are eligible for the [PEFC] scheme, whether or not they meet these requirements" (FAO 2018).

► Managed forests

Beside forest conversion to plantations or non-forest land, the FSC certificate introduced the intact forest landscape concept in the principle 9 'high conservation values' in the so-called Motion 65 since 2014. The new regulation requires forest managers to protect 80% of IFL within their management unit national standards are in place. Standards Developers may develop a threshold different than 80% through processes (FSC 2018a). For example, the Russian standard proposes for already certified areas a stepwise 80 %, 50 % and 30 % approach, where in the end only 30 % of the IFL area is left unmanaged. "However, the possibility of the zoning of IFL and identification of IFL parts where management activities are permissible is available only until January 01 2022. After this date, newly certified IFL shall be completely excluded from management activities (i.e. "strict conservation" will be established for 100% of the area)" (FSC 2020c). Another example is the national standard for the Republic of the Congo, which allows management activities on 50% of IFL areas (FSC 2020c). However, the claim of not using 80 % IFL areas leads to the discussion whether companies will commit to FSC certification in the future and if not whether IFL areas would be harvested by companies without any protection of IFL areas (Kleinschroth et al. 2019).

The PEFC Forest management standard requires only to "identify, protect, conserve or set aside ecologically important forest areas". However, it is stated that "this does not prohibit forest management activities that do not damage the important ecologic values of those biotopes" (PEFC 2015).

The FSC certificates are a sufficient indicator to reduce the risk of land use change from primary forest to commercial forest and plantation forests to a certain extent, depending on the implementation of the IFL policy in the national standards.

PEFC certificates cannot be used to reduce the risk of land use change from primary forest to commercial forest or to plantation forests.

### 3.4.2 Risk of land use change per region of wood origin

► Central/ Southern Europe: Austria, Belgium, France, Germany, Poland, Czech Republic, Portugal, Spain

Primary forests have almost completely disappeared in Central and Southern Europe due to centuries of deforestation and forestry. The area of primary forest or forest undisturbed by humans in the countries of Central and Southern Europe relevant for German paper production is less than 100,000 ha (Sabatini et al. 2018 and Forest Europe 2020). European countries with primary forest areas over 50.000 hectares would be Finland, Norway, Ukraine, Bulgaria and

Romania (Sabatini et al. 2018). As illustrated in (FAO and UNEP 2020) and based on OECD (2019), there are hardly any intact forest landscapes in Southern and Central Europe.

In Germany, the unmanaged forest area is only 2.8% of the forest area (as of 2019) (BMU 2020) and the primary forest area is 59.300 ha (Sabatini et al. 2018), which is 0.05% of the German forest area.

According to (Sabatini et al. 2018), most of the primary forest in the countries of Central and Southern Europe relevant for the wood supply of paper production is protected, but primary forests are under strict protection (International Union for Conservation of Nature (IUCN) category I) only in Spain (92%), Portugal (25%), Austria (11%) and the Czech Republic (7%) (Sabatini et al. 2018). In addition, (Keenan et al. 2015) documents a small net forest area increase for the years 2005 to 2015 for the countries considered here.

Accordingly, the risk of a land use change from unmanaged forest areas to managed forest areas in Southern and Central Europe is relatively low.

As there are no IFL areas in the countries under consideration in Central and Southern Europe, protection of primary forest areas are not directly covered by FSC standards.

- Northern Europe: Finland, Sweden, Estonia, Norway

The Northern European boreal forests of Scandinavia and the forests of the Baltic States still have relatively large areas of intact forests (OECD 2019).

In Northern Europe, 1,1 million hectares of primary forests were mapped by (Sabatini et al. 2018) and 2.8 million hectares of forests “undisturbed by man” by (Forest Europe 2020). The difference between the mapped areas of primary forests in (Sabatini et al. 2018) and the estimated undisturbed area in (Forest Europe 2020) may result from very limited spatial data-sets that could be derived for Sweden and the Carpathians in (Sabatini et al. 2018)[2]. (OECD 2019) reports 2.29 million hectares of IFL for Sweden, Finland and Norway, with 50% in Sweden and 42% in Finland.

In Estonia, Finland and Sweden, more than 95 % of these primary forests are protected, e.g. in national parks (IUCN category II). Only in Finland are 55% of the primary forests under strict protection (IUCN category I). In Norway, on the other hand, only 6% of primary forests are under a protection regime (IUCN category II) according to (Sabatini et al. 2018). (Keenan et al. 2015) show that the natural forest area in Estonia and Norway has slightly decreased and the intensively managed forest area in Norway has increased. In Sweden, there has been a strong decrease in natural forest area and an increase in planted forests. It is not possible to say to what extent these are primary forests due to a change in classification between FAO statistics for individual years (Keenan et al. 2015). In Finland, the natural forest area has remained more or less stable over the past 15 years, while the intensively managed area has increased, leading to an increase in total forest area. The statistics from (Forest Europe 2020) or OECD (2019) show that the total forest area or IFL area has remained more or less stable in Northern Europe through the last 2 decades.

Due to the much larger area of remaining primary forests compared to the Central and Southern European countries studied, the risk of land conversion from primary forest areas to commercial forest areas is higher in Northern Europe compared to Central Europe. Wood from the Baltic

[2] The primary forest area mapped for Sweden (0.03 million hectares in Sabatini et al. 2018) is far below the current estimate published in (Forest Europe 2020) (2.3 million hectares).

States or Sweden has the potential to convert less intensively used forests to more intensively used forests.

The FSC national Standard for Sweden includes regulation regarding forest management above the nature conservation boundary in Sweden and in IFL. "These forests are exempt from all management activities except those with the purpose of promoting natural biodiversity." (FSC 2020b). However, primary forests that are not mapped by the ILF framework are not addressed by this FSC regulation. The IFL policy has not been implemented in the national FSC standard of Finland (FSC 2010), therefore the international generic FSC indicator applies to protect 80% of the IFL within the management unit. There is no national FSC standard for Norway.

► North America: Canada, USA

Canada and the USA together possess 29 % of the world's intact forest landscapes with 286 million hectares in Canada and 49 million hectares in the USA (OECD 2019). According to (Keenan et al. 2015), the USA recorded a net increase in forest cover of 275 hectares per year from 2010 to 2015. Canada, however, shows a loss of natural forests of 408.000 ha per year in favour of highly intensified forestry. OECD (2019) shows that 3,6 million hectares of intact forest landscape area were lost in Canada and 0,6 million hectares in the US from 2013 to 2016.

Due to the large area of remaining primary forests and the still existing decline in intact forest area, there is a potential risk that primary forest areas will be converted into commercial forest areas, even if net forest area in the USA increases.

The IFL policy has not been implemented in the national FSC standards of Canada and the USA (FSC 2018b; FSC 2018c), therefore the international generic FSC indicator applies to protect 80% of the IFL within the management unit.

► Russia

Russia accounts for 21 % of the world's intact forest landscape area (OECD 2019). Land conversion from natural forest to other land uses is about 87.000 ha per year (Keenan et al. 2015). However, 9,5 million hectares of intact forest landscape area were lost from 2013 to 2016 (OECD 2019). Russia thus shows a loss of primary forests in favour of highly intensified forestry.

For a given softwood content in paper of 20 % from North Europe, less than 2 % of the wood is purchased from Russia. However, the wood coming from Russia could be related to the conversion of primary forests into managed forests.

The IFL policy has been implemented in the national FSC standards of Russia in 2020 (FSC 2020c). For already certified areas a stepwise 80 %, 50 % and 30 % approach is applied, where in the end only 30 % of the IFL area is left unmanaged. "All newly certified IFL (after January 01, 2022) "shall be completely excluded from management activities" (FSC 2020c).

► South America: Brazil, Uruguay and Chile

The results of (FAO and UNEP 2020) show that the largest area conversion of intact forests takes place in South America. Brazil has 20% of the world's intact forest landscapes at 229 million hectares, Chile has 13 million hectares, while Uruguay has no intact forest landscapes according to (OECD 2019). According to (Keenan et al. 2015), in Uruguay and Chile both the natural forest area (22,800 hectares per year) and the plantation area (300,800 hectares per year) increased in the years 2010 to 2015. OECD (2019) shows that the intact forest landscape area has remained more or less stable in Chile; while 4,2 million hectares of intact forest landscape area were lost from 2013 to 2016 in Brazil. This is offset by the annual increase of 152.600 hectares of forest plantations, which means an annual net forest area loss of almost one million hectares (Keenan et al. 2015). In (Câmara et al. 2015), the GLOBIOM-Brazil model (Global Biosphere Management Model) is used to project land use change from 2020 to 2050 in Brazil. The results show that with implemention of the Brazilian Forest Code in 2012, forest plantations would increase from 7,65 million hectares in 2010 to 16 million hectares in 2050. However, the modelling shows also that by 2050, 11% of primary forests outside protected areas will still be harvested. In (Pendrill and Persson 2017), various global and regional geo-data sets on land cover are analysed to identify the post-loss land cover of previously deforested areas in Latin America. The results of this study indicate that one third of the post-loss land area is for forestry purposes. However, according to the authors, this is largely due to difficulties in combining global data sets. The currently published studies do not provide information on how much of the Brazilian rainforest is converted into forest plantations or commercial forest. However, that a land use change from natural forests to forest plantations takes place can be seen from a statement on the calculation of carbon loss in (Câmara et al. 2015).

There is therefore a realistic risk that primary forest will be converted for Brazilian timber plantations.

According to (Neeff and Linhares-Juvenal 2017), the plantation certification system FSC prohibits the conversion of primary forests in Brazil. Based on this report and the PEFC rules mentioned above, PEFC certification cannot be used to exclude the risk of conversion of primary forests.

### 3.4.3 Discussion of the risk of land use change

The analysis shows that it is almost impossible to guarantee that wood from any given region, where there is still primary forest, does not come from areas that have undergone conversion from primary forest to managed forest or forest plantations in recent years. However, it can be concluded that the risk of primary forest conversion in Central and Southern Europe is relatively low due to scarcely existing primary forest and the strict national protection policies for primary forests in some countries.

Due to the still existing larger areas of primary forests in the Scandinavian countries, the Baltic States, Russia, USA and Canada, the risk of land conversion from primary forest areas to commercial forest areas is higher compared to Central Europe. In particular, the risk of primary forest conversion in Canada and Russia is not considered negligible.

Wood from Brazil is also subject to a high risk of originating from areas converted from primary forest. Even if the net forest area in Uruguay and Chile increases and IFL areas in Chile remain stable in Chile, there is still a risk of land conversion from forest to forest plantation.

**Summary: land use change**

In all regions examined in this study, there is a potential risk of land conversion due to the supply of wood for pulp and paper production, except in Central and Southern Europe, where the risk is very low due to almost non-existent intact forest landscapes. So far, the best way to avoid the risk of further land conversion as much as possible is

Priority A: to use recycled fibres

Priority B: to supply wood from countries without relevant primary forest area (Central and Southern Europe)

- from certified plantations based on the certification schemes FSC

- from countries like Sweden with national FSC standards where at least not all primary forests but all IFL areas are protected

- generally, from FSC-certified forests where at least a certain proportion of IFL area is protected.

## 3.5 Carbon storage in forests

Forests are one of the most important carbon sinks in the world. Between 1990 and 2015, the carbon stock in forests decreased by 13,6 billion tonnes (Köhl et al. 2015). The decline in carbon is mainly due to the decrease in forest areas in South America and West and Central Africa. In these regions, the carbon stock per area is higher than in other regions of the world, so that the loss of forest area has a greater impact here than in other regions (Köhl et al. 2015).

The greatest carbon losses result from the conversion of forest systems to other forms of land use. To address this, land use change has been included in the calculation of national greenhouse gas inventories. The existing calculation rules (IPCC 1996; RL 2009/28/EC (European Commission 2018); PAS2050-1 2012) only include land use change from and into forest systems. A land-use change between different forests systems such as primary forest, forest plantations or between commercial forests managed with different intensity is not addressed.

Therefore, established calculation rules and inventories cannot be used to assess the impact of different management practices on the carbon balance of forests and long-term carbon storage in different regions.

This was also demonstrated in the study of (Harris et al. 2015), a meta-analysis with the aim to quantify the effects of land use change for bioenergy sources. This study showed that the study situation is insufficient to calculate changes in soil carbon content and greenhouse gas emissions due to land-use changes caused by short-rotation forestry[3]. The case study of (Juntheikki 2014) estimates the carbon sequestration potential in eucalyptus plantations in Uruguay. However, the calculations of (Câmara et al. 2015) include a carbon loss for land use change from natural forest to forest plantations.

For forests in the Northern Hemisphere, (Jandl et al. 2007) analysed which forms of forest management have a positive or negative impact on carbon storage in forests. It is evident from this study that the extension of the rotation period leads to an increase in carbon storage. Although short rotation periods maximise above-ground biomass production, they do not maximise soil carbon storage (Jandl et al. 2007). This statement is supported by studies on unmanaged forests in temperate latitudes, which show a steady increase in the biomass carbon pool with increasing age (Jandl et al. 2007). Furthermore, the disturbance events leading to soil carbon loss are reduced by longer rotation periods. In contrast, monocultures show negative effects on carbon storage. Forestry should be designed to promote stability of forest ecosystems, the accumulation of above-ground biomass and the formation of carbon-rich forest soils (Jandl et al. 2007). (Bravo et al. 2015) also recommend "maintaining or increasing the landscape-level carbon density through forest conservation, longer rotations, fire management, and pest and disease control" to increase carbon stocks in forests. In addition, according to (Bravo et al. 2015), forestry techniques appropriate to the site, such as thinning, partial harvesting or adaptation of species composition, can lead to an increase in carbon stocks. However, (Jandl et al. 2007) show that thinning and partial harvesting can lead to losses in soil carbon content.

[3] Short rotation forestry in Harris et al. 2015 is defined with an average rotation period of 18 to 20 years. The following species are mentioned as examples: Eucalyptus, Alder, Birch, Sycamore, Conifer, Beech, Poplar

**Summary: carbon storage in forests**

To maintain or even increase the carbon stored in the forests, German paper production should seek to ensure that

- the share of recycled fibres is maximized,
- wood from temperate and boreal forests originates from forest management that aims to promote both soil carbon content and carbon content of the above-ground biomass,
- wood from eucalyptus plantations is not associated with land use change from natural forests,
- wood from commercial forests with long rotation periods should be given preference.

**Note on rotation period length**

The tree species-specific rotation length as the average production or harvesting time depends on the desired target diameter, i.e. the assortment-specific production targets, as well as on other factors such as yield expectations, liquidity considerations or production risks. This means that the rotation length always depends on the respective forest management and the production target in the respective geographical area, and therefore does not represent an absolute value. The wood production datasets used in this study are based on (Ecoinvent 2019) and assume the following rotation periods for Germany: 100 years for spruce, 120 years for pine, 140 years for beech and 140 years for oak. For the Nordic forests, a rotation period of 80 years is assumed for pine and spruce according to the Ecoinvent datasets.

The range of rotation lengths depending on the forestry objectives can be seen from the alternative WEHAM scenarios (Oehmichen et al. 2018). In the timber preference scenario, for example, rotation periods of 80 years for spruce and pine, 103 years for beech and 113 years for oak were defined; in the forest vision scenario with focus on nature conservation, rotation periods for all tree species that are part of the present potential natural vegetation were increased to 140 years for pine, 200 years for beech and 250 years for oak.

According to the alternative WEHAM scenario "wood preference scenario" and (Felton et al. 2017), the highest mean annual increment of wood for spruce and pine in Germany and Sweden is to be expected at a rotation time of about 80 years. The preference for wood from commercial forests with long rotation periods could therefore mean that wood origins with a longer rotation period than the rotation period determined by wood increment should be preferred.

# 4 Considerations on paper recycling

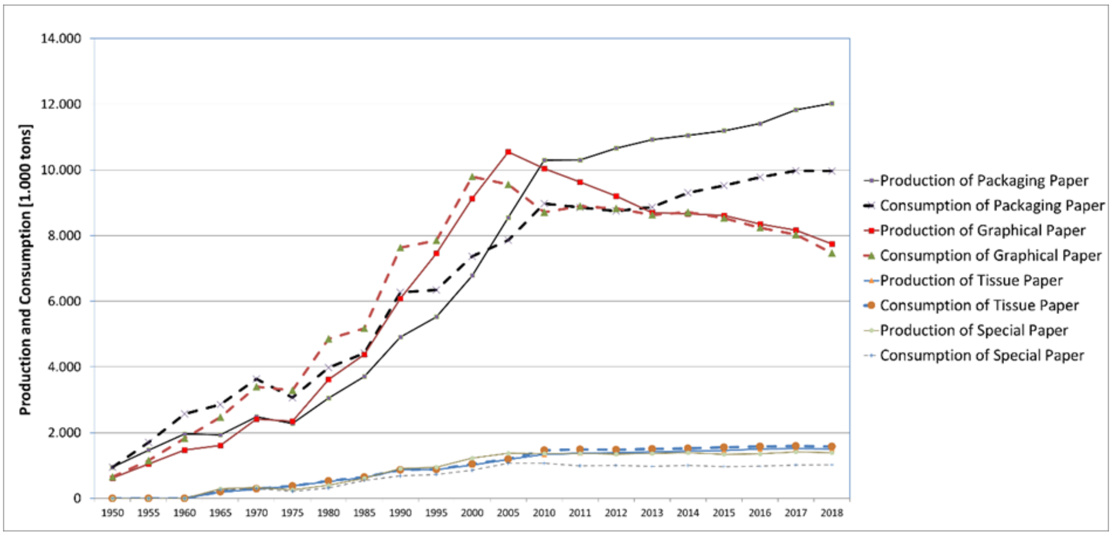
## 4.1 The German paper cycle in 2018

This section intends to provide a better understanding on how the paper cycle related to office and tissue paper can be strengthened and on how Eco-labels can contribute to this objective. However, to avoid misconceptions, it must be emphasized here that the need for virgin fibre input into the German market to ensure a fully operational fibre cycle is beyond question. The purpose here is rather a matter of further exploiting existing potentials for recycling of paper fibres.

The development of paper production and consumption is illustrated in 40separately for the four main paper types. The consumption of tissue paper and special paper has been relatively stable over the past ten years, amounting to 1.581 and 1.020 thousand tonnes, respectively, in 2018. In contrast, consumption of graphic papers has been declining continuously since 2000 to 7.467 thousand tonnes in 2018 (-25 %). In all likelihood, this development has affected mainly newspapers and magazines, but also office papers to an extent. In contrast, the consumption of paper for packaging purposes increased steadily to 9.965 thousand tonnes in 2018, representing an increase of about 35 % since 2000.

While the production and consumption volumes of graphic, tissue and special papers were relatively similar in 2018, there was a distinct net export surplus for packaging paper, board and carton (hereafter: "packaging paper"), which has been evident for about 10 years. The main drivers for the increase in consumption of packaging paper are the growing importance of distance trade and the increased use of outer packaging in stationary retail displays, i.e. for the presentation of goods on store shelves (Detzel et al. 2020).

**Figure 40: Timeline of paper production and consumption by paper type in Germany**

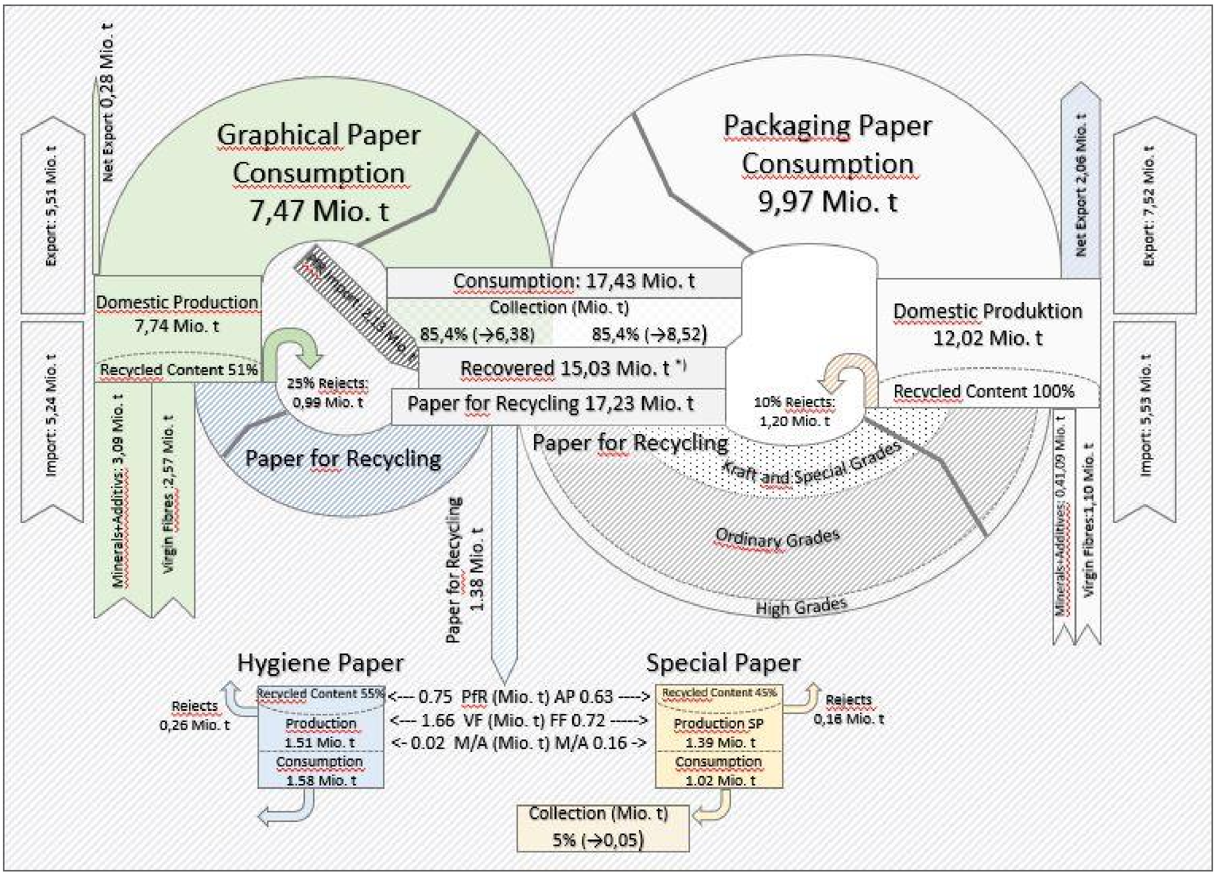



Source: (Moldenhauer et al. 2019); „Packaging paper" comprises paper, board and carton

Office paper accounts for approximately 600.000 tonnes of graphic paper consumption, which is 8 % of graphic paper consumption. The share of recycled paper in office paper is 84.000 tonnes (14 % of office paper consumption). According to (Detzel et al. 2008), the share of recycled paper was 80.000 thousand tonnes in 2006, which indicates a certain stability against the market trend. For tissue paper, the share of recycled paper amounts to approximately 290.000 tonnes (18 % of tissue paper consumption).

Although the focus of this study is on office paper and tissue paper, reflections on furthering paper recycling in Germany require an understanding of the entire paper flow.

**Figure 41: Material flow chart for the paper cycle in Germany in 2018**




Source: ifeu, adapted from (Putz and Schabel 2018); *) includes collection of used special paper for recycling

The German fibre and paper flow are schematically depicted in Figure 411 and reveals that:

- the two main "circulation systems" within the German paper material flow are the production of graphic paper and packaging paper and their collection and recycling in the form of paper for recycling
- from the graphic paper cycle, significant quantities flow into the production of packaging paper and smaller quantities into the production of tissue paper and special paper
- material loss in the form of rejects is particularly high when returning used paper to tissue paper production (assumption here: 40 %), and relatively low when returning used paper to packaging paper production (assumption here: <10 %)
- direct virgin fibre input into German paper production is highest for graphic papers
- virgin fibre is also supplied by importing finished papers to the German market (see arrows on the outer left and outer right side of Figure 411). The import of graphic papers and packaging papers is on a comparable scale.

## 4.2 Key factors for increasing paper recycling in Germany

Figure 411 indicates that, in theory and on average, there are still untapped potentials for increased input of paper for recycling (hereafter: "PfR") especially into graphic paper production as well as, to a lesser extent, into tissue and special paper production. However, assuming a static situation, i.e. a steady amount of German paper production this would require additional PfR being made available. Potential sources for that are discussed in the following.

### 4.2.1 Collection and sorting of PfR

Increased quantitative and/or qualitative collection of used paper

Not all paper products in circulation can be collected separately and returned for material recycling. According to the European Paper Recycling Council „due to non-collectable non-recyclable paper products the current theoretical maximum paper recycling rate is in fact only 78 %" (EPRC 2020a). Within a German context it is generally assumed that it affects approximately 15 % of consumed papers, particularly special paper and tissue paper as well as "losses due to archiving, contamination etc." (Schönheit and Trauth 2013). The current collection rates of graphic and packaging paper in Germany already are at that level and therefore the additional technical collection potential for these two paper grades is marginal.

On the other hand, there still seems to be room for improvement regarding the quality of the used paper collected. This is also essential because contamination of used paper should be avoided as far as possible to make effective use of the physical recyclability of the fibres. (Schönheit and Trauth 2013), for example, propose "bundle collection by paper grades and separate collection in offices for white used paper and cardboard". They also point out that "paper processing and finishing must be strictly recycling-friendly from the outset - especially with regard to adhesives and printing inks" and call for "limit values for non-paper components and unwanted materials as well as a quality guarantee for used paper delivered to paper mills".

Improved/advanced sorting of used paper

According to (Umweltbundesamt 2015), there is a general "trend in used paper sorting to improve the degree of purity of used paper types and to switch to the increased use of automated, opto-electronic and sometimes multi-stage sorting equipment with subsequent manual quality control. Without re-sorting, considerable quantities of deinkable used papers are lost (20 % -40 %) via the output streams of sorting plants. This loss can be reduced by about 50 % by integrated re-sorting, which also improves the quality of the produced types and the overall marketing result.

At present, however, it must be assumed that such re-sorting is not the general rule. For example, a study carried out in 2018 on the composition of used paper in Germany showed that the examined mass of paper for recycling grade 1.02 (mixed waste paper) contained 64 % (mass percent) of graphic paper, more than twice as much as the proportion of packaging paper (Schabel 2019). Likewise, (Faul et al. 2018) report typical contents of graphic paper in mixed used paper of between 50 % and 65 %.

The fraction that after sorting goes into production of packaging paper therefore still contains considerable quantities of graphic paper. Here, improving sorting efficiency could allow further quantities of graphic waste paper to be recovered to optimise the recycling cycle. Although EN 643 is available for the regulation of the quality of paper for recycling, it appears not to be always followed to the desired extent in market reality. In addition, EN 643 in its current version might not be sufficient "to derive the quality of the individual paper for recycling grades in terms of their potential for producing new paper and cardboard products" (Schabel 2019).

The high proportion of graphic paper in mixed waste paper could also be partly due to the fact that, contrary to EN 643, the used paper collected in the blue bin (paper for recycling grade 5.01), which should be sorted into the three fractions, i.e. mixed paper for recycling (grade 1.02), mixed papers from department stores (grade 1.04) and paper for deinking (1.11), might be declared as paper for recycling grade 1.02 without further sorting and marketed as such (ifeu 2020).

### 4.2.2 Imports of PfR

Overall, the European paper recycling rate is at 72 % in 2019 (EPRC 2020b) and statistics in (Moldenhauer et al. 2019) show large ranges of waste paper collection rates and PfR use rates between European countries. Several EU countries such as Hungary, Slovenia, Czech Republic, the Netherlands and Denmark still have significant potential for increasing the recovery of used paper. While under current market conditions a build up of additional recycling capacities in those countries is not very likely due to the high capital intensity of pulp and paper production. Additionally, collected amounts of PfR might be used in countries with already well developed recycling capacities such as Germany.

### 4.2.3 Technological recyclability

(Meinl et al. 2017) calculated the average fibre age for the European Union incl. Norway and Switzerland to be 3,6 in 2016, but according to (Putz and Schabel 2018) "this does not indicate the maximum possible technological recycling rate". Rather, they derived the following key statements from the available literature on multiple recycling studies of newsprint papers:

- "Even after four or five recycling cycles, the quality level of the newsprint paper produced is satisfactory and the papers were easy to print".
- "The optical parameter whiteness, which is so important for graphic papers, is 18 % lower after five recycling cycles compared to unprinted virgin fibre paper. It is noticeable that whiteness is reduced from 67 % to 60 %, i.e. by 11 %, already after the first recycling cycle. The following four recycling cycles only exacerbated the whiteness loss by a further 7 %".
- "Fibre replacement in the German paper cycle occurs mainly in the field of graphic papers"

(Putz und Schabel 2018) achieved a total of 25 (additional) recycling cycles without any addition of virgin fibre in their own studies on multiple recycling of a corrugated cardboard paper mixture. Based on their own experiments and other literature sources, they conclude that:

- "The simplistic statement that paper fibres can be recycled four to seven times, after which they are too weak to be used to produce more paper, is disproved".
- "Older literature shows that for various virgin fibre materials with up to 12 recycling cycles, the greatest changes occur during the first two to four cycles.”

However, they also pointed out that "the challenge facing paper mills when using paper for recycling as a raw material for paper production primarily is the separation of impurities and non-paper materials coming along with paper products. These materials cannot be removed completely, which leads to a deterioration in quality through multiple rounds of recycling. It would be desirable for manufacturers of paper products to focus more on recyclability when designing such products" (Putz and Schabel 2018). The evaluation of recyclability is usually done by means of INGEDE methods for assessing recyclability (INGEDE 2013). According to (Blauer Engel 2021), "printed products are considered to be verifiably deinkable if they comply with the guidelines of the "Deinkability Scorecard" after application of INGEDE test methods and, in case of adhesive applications, with the "Removability Scorecard" of the European Paper Recycling Council (EPRC)".

It is also worthwhile to mention that German paper production in 2018 used 5,5 million tonnes of virgin fibres (chemical pulp and mechanical pulp) and approximately 14,5 million tonnes of recycled fibres (see Figure 411). Additional virgin fibre input was provided by imports of finished paper and paper products. According to (Moldenhauer et al. 2019), more than 50 % of the imported paper volume (approx. 11 million tonnes) in 2018 originated from three countries: Sweden (20 %), Finland (19 %) and Austria (12 %), whose share of paper for recycling in the respective national paper production was 11 %, 6 % and 46 % (in 2017). Based on the above percentages, the inflow of virgin fibres with paper imported from these countries to Germany would amount to approximately 4.6 million tonnes. However, since the average virgin fibre content of imported and exported papers is not known, the exact share of virgin fibre in German paper consumption cannot be determined with absolute precision.

(Schönheit and Trauth 2013) assumed in their study that due to the large quantities of imported paper with a high virgin fibre content in combination with the large quantities of exported paper with a high recycled fibre content, the share of paper for recycling in total paper consumption could be significantly lower than the paper for recycling rate in production suggests. The authors of the present study agree that this assumption may still be valid given the present paper and fibre flow data in Germany.

This also supports the assumption that the technical recyclability of fibres in the German fibre cycle is far from being exhausted.

## 4.3 Blue Angel and the EU ecolabel criteria for office and tissue paper

The study aims amongst others to make recommendations regarding the further development of the paper related ecolabels in the German and EU context. Potential action points are identified in this section.[4] The current criteria for awarding the Blue Angel and the EU Ecolabel are:

- Blue Angel for graphic paper and carton made from 100 % paper for recycling
  DE-UZ 14a (Date: 1/2020)
- Blue Angel for end products for office and school supplies
  DE-UZ 14b (Date: 1/2018)
- Blue Angel for tissue paper
  DE-UZ 5 (Date: 7/2014)
- EU Ecolabel for graphic paper, tissue paper and tissue paper products
  Commission Decision (EU) 2019/70 of 11.01.2019
- EU Ecolabel for printed paper. The old version 2012/481/EU has a duration until 2022. The new version, according to Commission Decision (EU 2020/1803) covers printed products, paper stationery and paper bag products and has a duration until 2028.

The Blue Angel sets out the following goals:

[4] The revisions of eco-labels 14a and 14b have been completed at the time of final editing of this study and the recommendations have already been implemented for the most part

- Conservation of resources, in particular forest ecosystems and thus the protection of species and climate, and the reduction of waste through the use of waste paper in the production of graphic or tissue paper, especially when using waste paper from household and commercial collection.
- Avoidance of environmental impacts directly associated with the production of chemical and mechanical pulp
- UZ 14b also aims to avoid technologically unnecessary substances during production and processing.

The EU Ecolabel aims at:

- Reduction of energy consumption and associated emissions to air
- Reduction of environmental damage by reducing water consumption, emissions to water and waste production
- Reducing environmental damage or risks arising from the use of hazardous chemicals
- Protection of forests by mandatory sourcing of recycled or virgin fibres from forests and areas managed in a sustainable manner.

Table 6 provides a comparison of the Blue Angel and the EU Ecolabel award criteria for office and tissue paper. For the sake of clarity and to provide a transparent structure, the criteria are subdivided into the following categories: fibres, product specifications, emissions/energy and waste.

Table 6: Comparison of selected criteria of the ecolabels under investigation

| Requirement categories: | Graphic paper and cartons incl. end products<br>DE-UZ 14a (1/2020)<br>DE-UZ 14b (1/2020)[5] | Tissue paper<br>DE-UZ 5 (7/2014)[6] | Graphic paper, tissue paper and tissue paper products - 2019-70-EU |
| --- | --- | --- | --- |
| **1. Fibres** | | | |
| A. Paper for Recycling (PfR) | Paper<br>100 % PfR<br>minimum 65 % PfR from<br>ordinary grades<br>medium grades<br>kraft grades<br>special grades.<br>maximum 35 % PfR from higher grade<br><br>End products:<br>Tolerance of 5 % materials other than recycled fibres<br>Minimisation requirements for inks, toner, printing ink, surface finishing agents, coatings and adhesives<br>Ban of diisobutyl phtalate | 100 % PfR<br>minimum 65 % PfR from<br>ordinary grades<br>medium grades<br>kraft grades<br>special grades<br>Exception<br>Crepe toilet paper: only<br>ordinary grades<br>medium grades<br>kraft grades<br>special grades<br>Crepe paper towels: only<br>ordinary grades<br>medium grades<br>special grades | minimum 70 % fibres from recycled sources (or proportionally from sustainable forestry[7])<br><br>Not creditable: recycled fibres that can be returned to the same process from which they originated (i.e. paper machine broke - self-produced or purchased).<br>Creditable: the supply of rejects from converting processes, provided that a delivery note according to EN 643 is available |
| B. Virgin fibre | *Not applicable* | *Not applicable* | Virgin fibre 100 % documented from legal sources<br>Ban of origin from genetically modified tree species<br>minimum 70 % fibres from verified sustainable forestry (or proportionally from recycled sources[8])<br>Independent supply chain certification, e.g. according to FSC or PEFC required |

[5] Some of the products covered by these award criteria currently do not safely comply with the requirements for recyclability according to criterion 3.8. However, recyclability is of great importance for the subsequent life cycles of the paper products. The Ecolabel Jury therefore expects that the recyclability of the products (according to Criterion 3.8 of these award criteria) will be further developed during the period of validity. The jury plans to change the current optional criterion 3.8 into a mandatory criterion in the next revision [DE UZ 5]. In the revised version of DE-UZ 14b dating to 1/2020, recyclability has already been implemented as a shall requirement.

[6] Ibid footnote 4

[7] Under this Ecolabel both, recycled and/or virgin fibres can be used as raw materials for paper production

[8] Ibid footnote 4

| Requirement categories: | Graphic paper and cartons incl. end products<br>DE-UZ 14a (1/2020)<br>DE-UZ 14b (1/2020)[5] | Tissue paper<br>DE-UZ 5 (7/2014)[6] | Graphic paper, tissue paper and tissue paper products - 2019-70-EU |
|---|---|---|---|
| **2. Product specifications** | | | |
| Whiteness | maximum 100 %<br>(DIN ISO 2470) incl. UV<br>optical brightening agents banned; Exception:<br>SC papers > 110 g/m2<br>Coated papers >75 g/m² | maximum 80 %<br>(according to DIN ISO 2470) incl. UV<br>optical brightening agents banned | no requirements for whiteness<br>optical brightening agents permitted<br>Tissue paper: proof of colour fastness required |
| Recyclability | End products:<br>In general:<br>Recyclable according to European Paper Recycling Council EPRC<br>In particular:<br>Deinkability<br>(Ingede Method 11)<br>Separability of adhesive applications<br>(Ingede Method 13)<br>Exception: redispersible and water-soluble adhesives. | No requirements | Printed paper:<br>In general:<br>Recyclability requested<br>In particular:<br>Deinkability to be proved<br>Coating and lamination with plastics only for covers allowed<br>Adhesives must be removable<br>Wet strenght agents must not hinder recyclability |
| Usability | specific requirements for individual product categories; e.g. copy paper:<br>Running properties<br>(DIN 12281)<br>Resistance to ageing<br>(ISO 20494)<br>Control of VOC emissions | No requirements | Proof of product quality according to EN ISO/IEC 17050<br>Tissue paper: Minimum requirements for absorbency |

| | | | |
|---|---|---|---|
| Emissions/ Energy | | | |
| Reference values for emissions and energy efficiency | Emission values for direct dischargers based on the lower reference values according to EU COM PPP BREF (2015) as well as Annex 28 of the Waste Water Ordinance for<br>CSB, $BSB_5$, AOX,<br>Total N,<br>Total P | No specific requirements | Acidification + Eutrophication:<br>Reference values for CSB, P, NOX, S and a sum value of those<br>AOX: Reference value for pulp<br>$CO_2$ fossil: Reference values for papers made from DIP, chemical pulp or mechanical pulp fibre<br><br>Energy efficiency:<br>Reference values for electricity and fuel |
| **Waste** | | | |
| Waste management | No requirements | No requirements | Proof of a waste management system must be provided.<br>EMAS or ISO-14001 certification suitable as proof. |

All ecolabels require specification of paper for recycling grades according to DIN EN 6432

The comparison reveals that the Blue Angel has a clear focus on requirements concerning used paper properties and recycling and that requirements for virgin fibres are therefore implicitly irrelevant. In the EU Ecolabel, the criteria for recycled fibres are less nuanced. For example, specifications for the quality of paper for recycling are not defined. For virgin fibres, the main requirement is that there must be proof of origin of only 70% of fibre from sustainable forest management. In addition, maximum values for certain emission values and energy consumption are defined by so-called reference values, both for virgin fibres and recycled fibres or the papers made from them.

## 4.4 Discussion

The information provided in the previous paragraphs suggests that the main routes for further increasing paper recycling in German paper production are:

- *Ensuring that paper products are recycling-friendly.* This would enable increased yields of high-quality recycled fibres, but it would also require that more paper products on the market are equipped with adequate adhesives and inks. However, so far it seems difficult to trace back the exact origin of non-recycling-friendly paper products and/or to implement binding measures of design-for-recycling at those sources.
- *Separation of graphic papers contained in the mixed waste paper fractions* for use as PfR in graphic paper production. While this would be possible e.g. by use of automated detection, it seems that there is not always sufficient incentive for market actors to do so.
- *Increased import of PfR.* This would require that generally more used paper is collected mainly in other European countries and transported to Germany in an eco-friendly

manner. However, the mass potential for such action remains unclear as it depends on collection efforts in potential source countries as well as on market dynamics.

- Eco-labels also may contribute to a strengthening of paper recycling and a recycled paper product market. Potential activities here include
- *Further adjustment of whiteness requirements.* Decreasing the maximum tolerated whiteness threshold to levels of 90 % ISO and below would probably reduce the competition for PfR fractions that have higher shares of virgin paper products equipped with optical brighteners. On the other hand, it could have a negative impact on the acceptance of eco-labelled paper products if they were only available at lower levels of whiteness.
- Introduction of a quota requirement country specific for the mandatory use of ordinary and medium grades of paper for recycling in the EU Ecolabel. This could be a way to steer a Europe-wide expansion and a more targeted and purposeful design of the collection systems.
- Increase the requirements for sustainable sourcing of virgin fibres in the EU ecolabel. The requirement of 100% FSC certified fibres based on a mass balance system would ensure that the amount of certified fibres used in an installation is equal to the amount of fibres needed for a corresponding amount of ecolabeled product.
- Introduction of specific criteria of test procedures used to prove deinkability and separability in future revisions of the EU Ecolabel for printed paper.

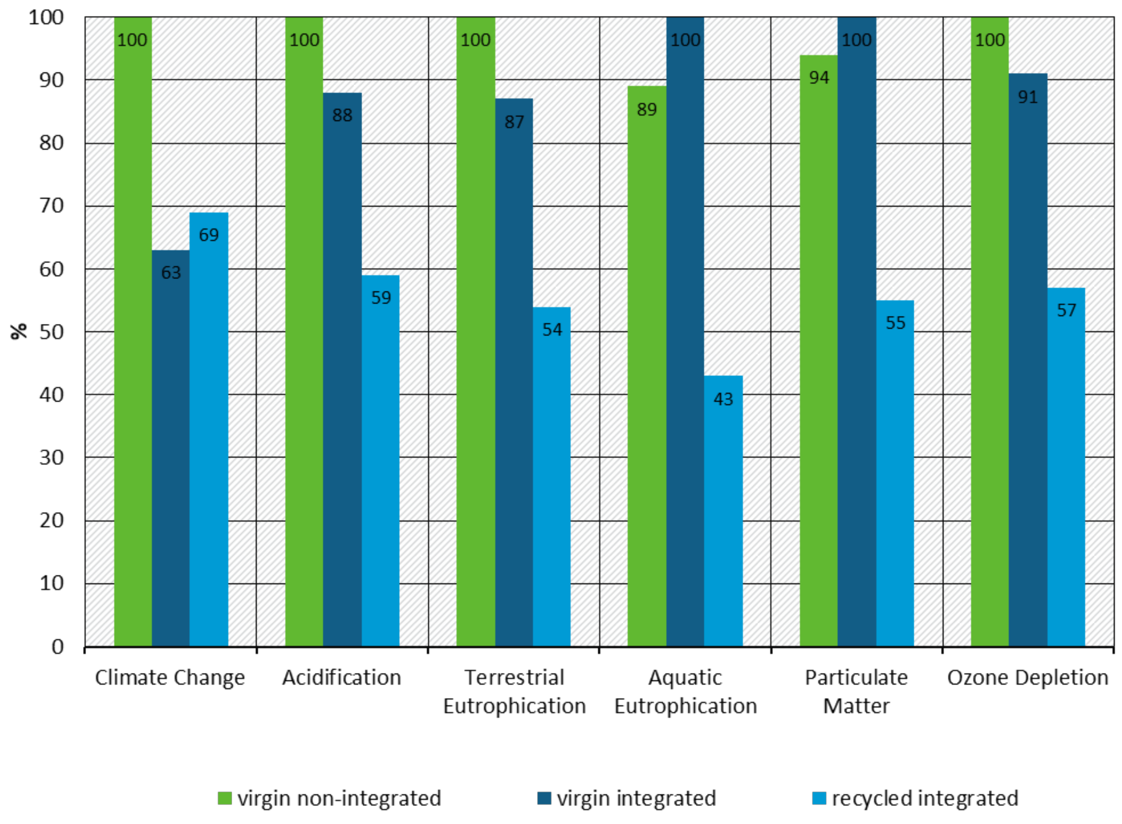
# 5 Conclusions

## 5.1 Life Cycle Assessment

The results of the life cycle assessment presented in section 2 show that recycled paper from integrated production generally performs considerably better than the virgin papers compared.

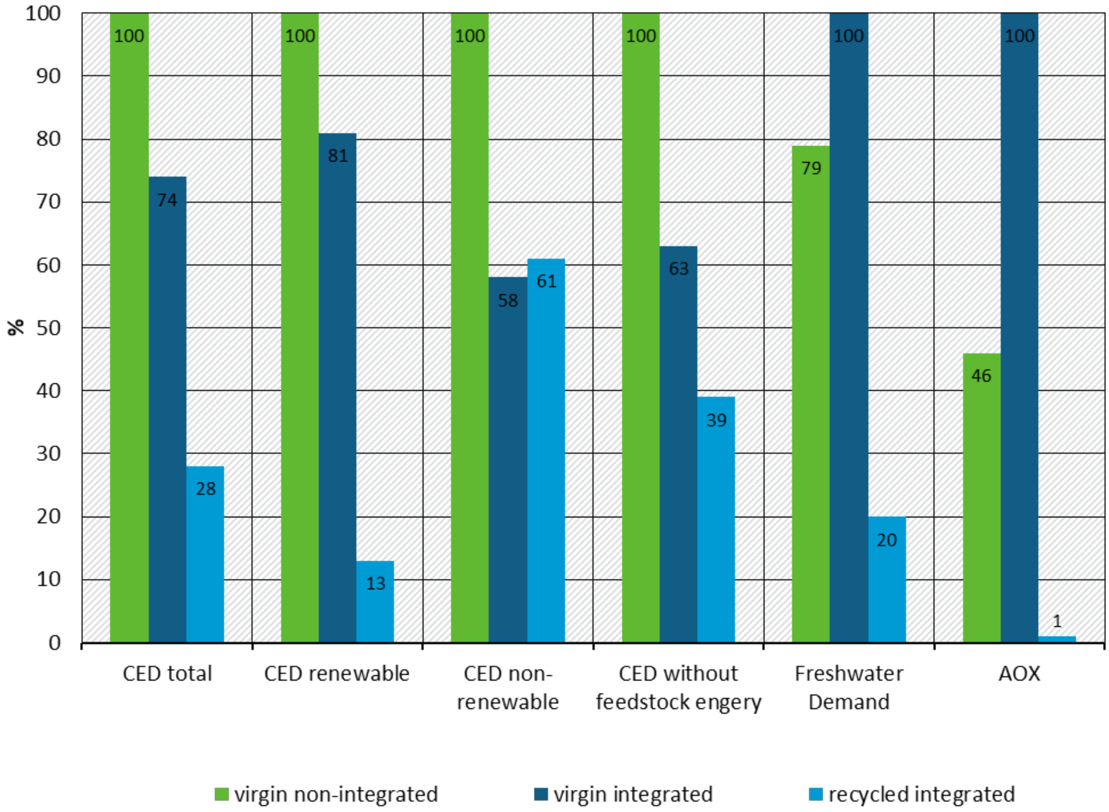
Figure 422, Figure 433, Figure 444 and Figure 455 show that in all assessed environmental impact categories for which results are considered robust, recycled office or tissue paper shows lower impacts than the respective virgin paper. (See section 2.1.1.4 for the data asymmetry for Photo-oxidant formation.) The only exception is to be found in the comparison of recycled office paper with virgin office paper from integrated production, where for one of the assessed impact categories (Climate Change) impact results are roughly on the same level. Main reason for the impacts of recycled office paper are the higher share of fossil fuel for steam production and the emission factor of the electricity used for production in Central Europe in 2015. The sensitivity analysis presented in section 0 shows that the recycled paper production with a potential future electricity production mix with higher shares of renewable energy sources will lead to lower impacts. Also, the decarbonisation of the production of process heat in the coming years will further improve the results of recycled paper for the impact category Climate Change.

**Figure 42: Comparison of impact assessment results: virgin non-integrated and integrated produced office paper vs. recycled integrated produced office paper**



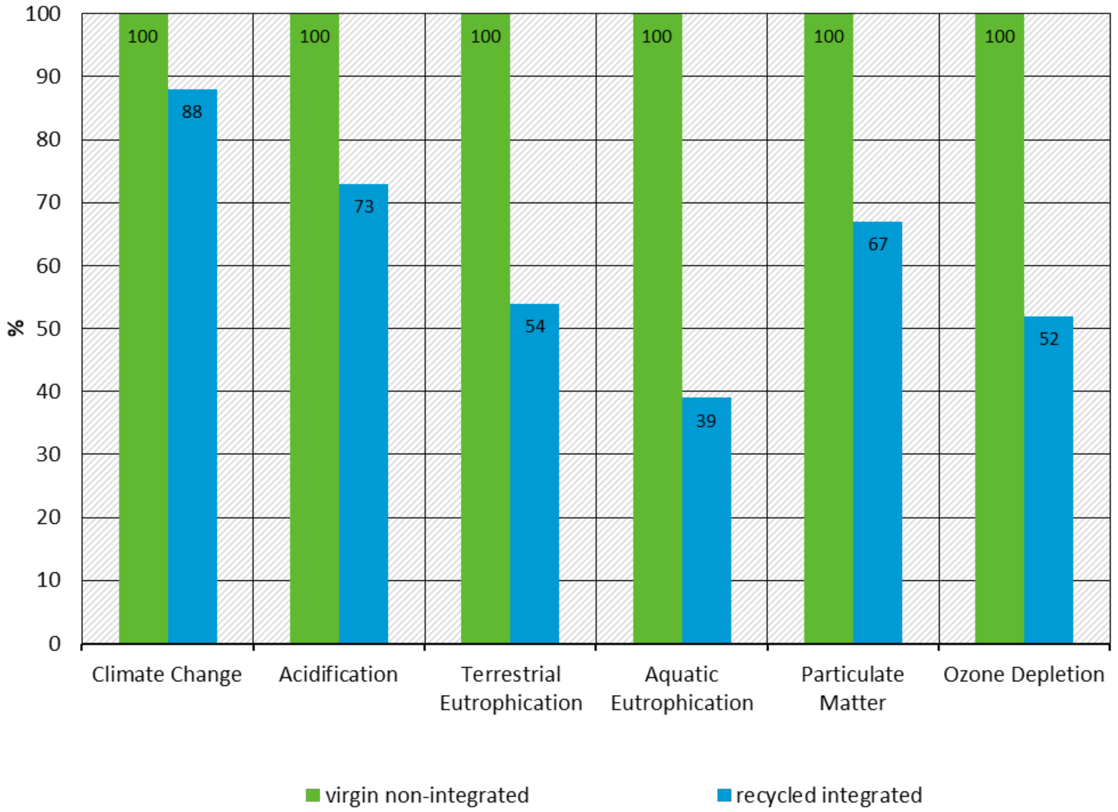

Source: (Own depiction 2021, ifeu)

**Figure 43: Comparison of inventory category results: virgin non-integrated and integrated produced office paper vs. recycled integrated produced office paper**



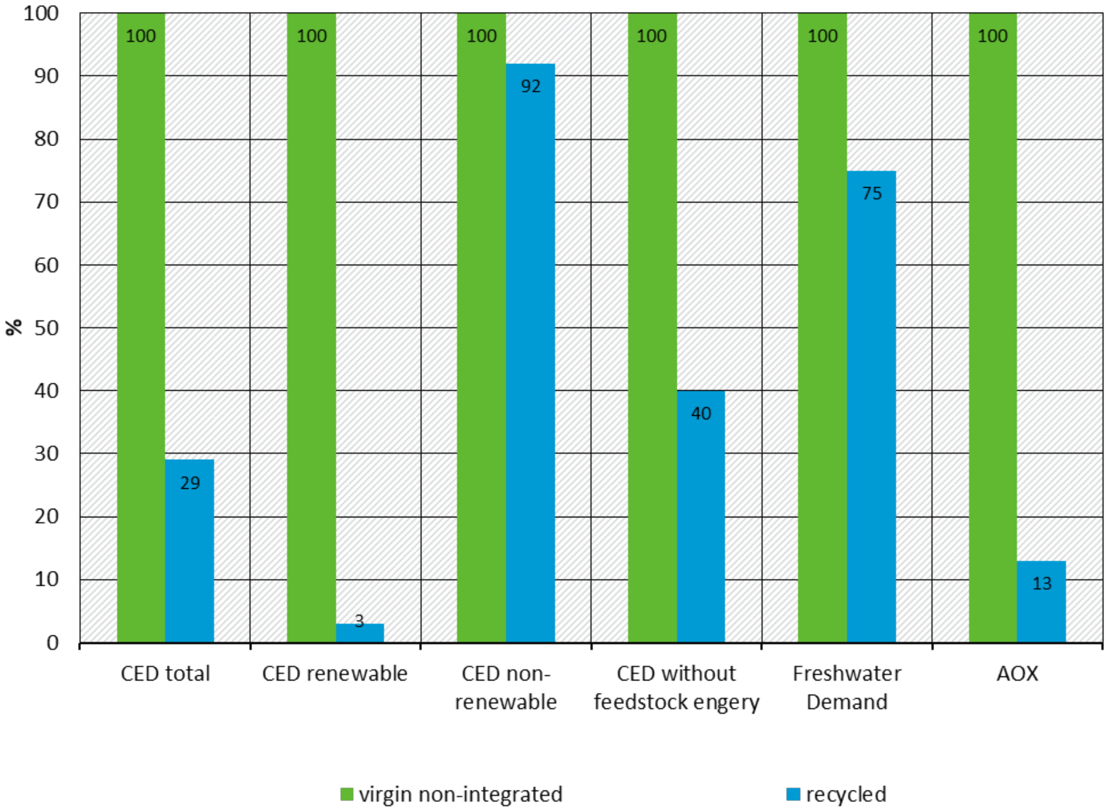

Source: (Own depiction 2021, ifeu)

**Figure 44: Comparison of impact assessment results: virgin non-integrated produced tissue paper vs. recycled integrated produced tissue paper**




Source: (Own depiction 2021, ifeu)

**Figure 45: Comparison of inventory category results: virgin non-integrated produced tissue paper vs. recycled integrated produced tissue paper**




Source: (Own depiction 2021, ifeu)

## 5.2 Impact of Wood Origins

The results and discussions of section 3 show that the pressure on forest areas is increasing both within Europe and globally. This is linked to potential losses of biodiversity as well as to restrictions on carbon storage in forests.

The implementation of the worldwide existing demands to protect forests and to enhance sustainable forestry cannot only be based on political nature conservation guidelines, but also means to reduce the general demand for wood.

**This leads to the conclusions:**

1. **to reduce the overall paper consumption,**
2. **to recycle as much paper as possible and**
3. **to reduce the share of primary fibres.**

**Even with existing measures such as certification schemes, negative impacts on carbon storage and biodiversity as well as conversion of primary forests cannot be safely avoided.**

The existing certification systems can only serve as quality requirements for environmental labels for the use of virgin fibres in paper production to a certain extent. Therefore, the use of recycled fibres can be used as the safest quality criterion for protecting forests and promoting sustainable forestry. In order to implement the certification systems according to FSC and PEFC criteria in a meaningful way into political instruments for ensuring forest management that is as natural as possible, the certification systems should provide measurable evidence on, for example, the level of human intervention (hemeroby) or conservation of biodiversity.

The following aspects have to be taken into account for the amount of wood or primary fibre required for the German paper supply: increasing the global carbon storage of forests and preserving biodiversity and naturalness.

This can be achieved first and foremost by ensuring that no primary forests are converted into managed forests or forest plantations. So far, beside the reduced consumption of paper and the use of recycled fibres, the best ways to avoid the risk of land conversion as much as possible is to supply wood from countries without relevant primary forest area (Central and Southern Europe), from certified plantations based on the certification schemes FSC, from countries like Sweden with national FSC standards, where at least not all primary forests but all IFL areas are protected, or generally from FSC-certified forests where at least a certain proportion of IFL areas is protected.

Even if forest plantations show higher results in terms of biodiversity loss potential, they could potentially reduce the pressure on primary forests. This of course is only possible if the forest plantations have not been directly or indirectly responsible for primary forest conversion, which in many cases might not be the case.

Wood from temperate and boreal forests, whose areas are not subject to conversion from primary forest, may be recommended from a biodiversity and carbon sequestration point of view if forest management is implemented with the aim of enhancing soil carbon content, carbon content of above-ground biomass and biodiversity through retention management or near-natural forest management. It should again be mentioned conventional clear-cutting should be avoided. Most European FSC and PEFC criteria catalogues contain criteria for measures that are key elements in retention forestry. Exceptions are the FSC and PEFC national standard for the Czech Republic and the PEFC national standard for Russia. However, currently available studies show that retention measures should be extended. Furthermore, the Russian FSC does not contain a guideline on the maximum size of clear-cuts.

To this end, policymakers are called upon to promote the use of recycled fibres in order to reduce the pressure on natural forests as well as to create an effective support programme for nature-oriented forest management and forest protection. This also includes the implementation of nature conservation measures in the state forest. In order to counteract the conversion of primary forests and to ensure that the wood or pulp imported into Germany does not come from areas subject to conversion of primary forests, the worldwide mapping of forest areas has to be further developed, national guidelines for strict protection of primary forest have to be implemented and the possibility of tracking supply chains must be promoted.

## 5.3 Paper Recycling

### 5.3.1 Strengthening the paper cycle

Increased use of PfR could and should be targeted predominantly in graphics paper production. With a paper for recycling input of 51% there seems to be considerable potential for increased use of recycled fibres in the German production of graphic papers. As mentioned above, the used graphic paper fraction in the mixed used paper could be exploited for this purpose by improved sorting. Here, waste paper sorting facilities should be called upon to assume greater responsibility in the future.

A limitation here – though quite manageable – could be the degree of whiteness required. After sorting, used graphic paper for recycling still contains small amounts of about 4-6 % brown grades (Steinbeis 2020). Therefore, the production of high-quality recycled paper requires thorough incoming inspection and sound recycling technology. For example, for recycled papers with a high whiteness, i.e. with whiteness levels of 90 and 100, specifically medium and high grades of paper for recycling are used. In the case of recycled papers with the Blue Angel label, this is done by combining those grades with the minimum amount of ordinary and medium grades demanded.

Still, the ordinary paper for recycling grades dominate the used paper market. While the degree of whiteness plays a relatively minor role for the LCA results of recycled papers, it is clearly controlled by the qualities of paper for recycling used in the recycling process. Acceptance by consumers for lower degrees of whiteness thus increases the usable range of paper for recycling. This applies to office papers in particular, as the market demands a particularly high degree of whiteness here.

As for recycling of tissue paper, an (at least partial) supply of paper for recycling could be provided by the specific collection of used tissue paper: there are some initial attempts to recycle paper towels (see Tork PaperCircle®, (Tork 2020)). However, this requires the establishment of a collection structure and the adaptation of the recycling process to handle wet strength agents and to ensure the sterility of the recycled paper.

Also, the greater recycling cycle that extends beyond German borders can be integrated via the demand for paper in Germany. The paper trade can be expected to ultimately react to signals of an increased market demand for recycled paper or papers designed for higher recycling contents by adopting a corresponding purchasing policy also for imports of intermediate and finished paper products.

### 5.3.2 Potential action points related to Ecolabels

Blue Angel, UZ 14a/b

The current version of the ecolabel award criteria UZ 14a includes a maximum ISO whiteness of 100 % as a mandatory maximum requirement during. However, lower whiteness levels could be advantageous for stabilising or even expanding the fibre cycle. It should also be noted that virgin fibres are physically only bleachable up to a whiteness of 90 %, and higher whiteness levels can only be achieved with optical brightening agents or use of PfR that already include these. These are therefore only effective under artificial lighting or in daylight. It would therefore be worth considering reducing the maximum whiteness for the ecolabel even further to 90 % or 80 % in the course of the revision. This would also reduce the need to use paper for recycling grades that contain high levels of optical brighteners. As a consequence, it could also be justified for the EU Ecolabel to set more stringent limits for optical brighteners in virgin and recycled fibre papers.

Moreover, the question arises whether recycled paper must necessarily have identical whiteness levels as virgin fibre paper. Rather, graded whiteness could serve as a distinguishing feature and be specifically addressed in consumer communication. Yet, although a whiteness of 70 % would be ideal for sustainability reasons, this could hamper the goal of promoting recycled paper from a marketing perspective.

Blue Angel, UZ 5

The processing of used paper for tissue paper production generates particularly high volumes of waste. Consideration should therefore be given to whether waste management requirements should be included for the award of the label, similar to those for the EU Ecolabel. At the very least, it should be ensured that any by-product streams with a high mineral and/or filler content are, if possible, recycled.

If necessary, more extensive requirements (e.g. specifications for the recovery of process water) to limit water consumption could also be considered, as this is a relevant technical parameter due to the purity requirements for tissue paper.

EU Ecolabel 2019-70-EU

The present LCA has demonstrated that process-related emissions and energy consumption during the production of recycled fibres are generally significantly lower than those of virgin fibres. Consequently, the fact that the Blue Angel UZ 14a/b and UZ 5 are only awarded for 100 % recycled paper continues to meet the targets set in the award criteria. Since the EU Ecolabel seeks to be applicable also to virgin fibre papers, it is only logical to limit their relatively higher specific process emissions and energy requirements for the award of the ecolabel by means of reference values. Thus, it also serves to conserve resources.

As implied in the previous sections, the quota requirement for the mandatory use of ordinary and medium grades of paper for recycling is essential for the promotion of the circular economy system. These are not yet included in the EU Ecolabel, but would be suitable to steer a Europe-wide expansion and a more targeted and purposeful design of the collection systems.

In the EU Ecolabel for printed paper, the current requirements for recyclability should be extended in future criteria updates by specificiation of test procedures used to prove deinkability and separability in analogy to those requested under DE-UZ 14b.

Increase the requirements for sustainable sourcing of virgin fibres in the EU ecolabel. The requirement of 100% FSC certified fibres based on a mass balance system would ensure that the amount of certified fibres used in an installation is equal to the amount of fibres needed for a corresponding amount of ecolabeled product.

## 5.4 Synopsis

The LCA results show recycled office and tissue paper has considerably lower impacts than paper from virgin fibres in almost all regarded environmental impact categories. Results of the sensitivity analysis regarding the application of a future electricity production mix show that the Climate Change impacts of recycled paper will further decrease with the progression of the energy transition. Therefore, the LCA results support UBA policy and Blue Angel requirements fostering recycled paper consumption.

The separate ecological assessment of wood origins leads, among others, to the following results:

- Eucalyptus from Latin American and especially from Southwestern European plantations are associated with a higher biodiversity loss potential than other hardwood from Northern or Central European forests.
- Even though Eucalyptus plantations can make an important contribution to carbon storage in forests, this is only true if their establishment has not been directly or indirectly responsible for primary forest conversion. It is almost impossible, though, to guarantee that wood from any given region, where there is still primary forest, does not come from areas that have undergone conversion from primary forest to forest

plantations in recent years. However, in the case of wood from FSC-certified commercial forests, at least a certain proportion of intact forest area is protected.

- Even with existing measures such as certification schemes, negative impacts on carbon storage and biodiversity cannot be safely avoided.

To decrease biodiversity loss and the risk of land use change, a reduction of the overall paper consumption should be sought. Furthermore, an increased use of paper for recycling may help to reduce the amount of primary fibres needed.

The main routes for further increasing paper recycling are:

- An improvement of the collection and sorting of paper for recycling in all European countries, f. e. by separating graphic papers contained in the mixed waste paper fractions for use in recycled graphic paper production
- An increased import of paper for recycling from European countries with a lesser demand for recycled fibres than Germany
- Lowering the degree of whiteness in recycled papers, especially for office papers

These measures can be at least partially supported by the use of ecolabels. Examples are decreasing the maximum tolerated whiteness threshold to levels of 90 % ISO and below in the UZ 14a Blue Angel label or the introduction of a quota requirement for the mandatory use of ordinary and medium grades of paper for recycling in the EU Ecolabel.

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