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IZNE Internationales Zentrum für Nachhaltige Entwicklung
International Centre for Sustainable Development

Ecological Comparison of the Use of

Sulphate Pulp, Wastepaper Material, and Grass-Based Pulp

in German Paper Production

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Commissioned by

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Introduction

The study examines the comparative ecological impact of using sulphate-based pulp, recycled fibre, and grass-based pulp in the German paper industry. It has been commissioned by CREAPAPER GmbH Hennef, which has a "GRASS FIBRE" business unit focussed on developing solutions for producing paper that is comprised up to 60% of grass-based pulp (GRASS PULP).

Research examining the use of alternative raw materials is currently booming in science and business. The goal is to use commonly found fossil materials in a more efficient way and replace or supplement them with as high a percentage of renewable resources as possible. In this regard, examining the comparative ecological impact seeks to determine the extent to which paper production in Germany can be made more environmentally sound.

CREAPAPER commissioned a study in 2012 for an ecological comparison of its own product, grass-based pulp used in paper production, with primary and secondary pulp made from wood. The Institut für Energie- und Umweltforschung Heidelberg GmbH performed the study and came to the conclusion that the production of grass pulp had less of an environmental impact and could be classified as beneficial.

There are, however, good reasons to justify a much more extensive investigation of the material in 2017. This is because since the last study appeared, procedures for collecting data about the value-added chain for pulp made of wood have improved considerably. One example of this is the availability of higher-quality and more accurate data on raw material harvesting and pulp production in places such as South America, which is the source of most German pulp imports. Not only does this make it possible to go beyond the geographically limited scope (Scandinavia) of the first study, but it also paints a much better picture of the countries of origin than would have been possible in the past.

Since 2016 it has thus been possible, with the help of the "ecoinvent 3.3" database, to include detailed information on wood cultivation, preparation, and subsequent transport in the analysis. Furthermore, a more extensive look at the value-added chain also yields a great deal more detail and precision. This has made it possible, for example, to create more accurate models of the value-added chain by considering 95% of the sulphate pulp used for paper production in Germany and its starting material.

Paper and Pulp Production in Germany 2016

The following data has been collected based on data and information provided by Verband Deutscher Papierfabriken (Association of German Paper Factories) and the International Trade Centre, supplemented by our own calculations.

The amount of paper products produced in Germany has fluctuated only slightly over the past few years. If 22.6 million tons of paper products were manufactured in Germany in the year 2016, this would correspond roughly to the amount produced as early as 2006. Compared to the previous year, there was therefore a slight increase of about 0.1% in the amount of paper produced. In 2016, production consisted of 50.3% paper, cardboard, and paper board for packaging purposes, 36.9% graphic paper, 6.7% hygiene paper products, and 6.1% for technical and specialised uses.

Approximately 4.5 million tons of pulp were used for this, with 3.4 million tons of this being imported to Germany. With a resulting import percentage of 76%, it is clear that German paper production is heavily dependent on foreign pulp production. While 1.6 million tons of pulp were produced domestically in 2016, 0.5 million tons of pulp were also exported. This shows a 0.2% increase in domestic production over the previous year.

This dependency on imports is caused specifically by the high demand for short-fibre sulphate pulp, which is obtained from fast-growing hardwoods. Short-fibre pulp is frequently obtained from Eucalyptus, which is native to the regions near the equator and is cultivated there. In 2016, short-fibre pulp comprised a little over two thirds of all pulp imports. The sulphate pulp considered in this study was mainly imported from Brazil, Finland, Sweden, Portugal, Chile, Uruguay, and Spain. Overall, the quantity of sulphate pulps imported from Europe was somewhat greater than that of non-European trade partners.

Pulp produced or imported domestically is not, however, the main source for German paper production. Recycling used primary pulp in the form of wastepaper was most significant. With a total of 16.9 million tons used and taking up 75% of the industry, wastepaper was, by far, the most important source of pulp in the German paper industry in 2016. In contrast to “fresh” pulp, wastepaper comprised the biggest proportion, with 15.9 million tons from Germany used and only another 1.0 million tons of pulp imported from abroad. This corresponds to an import percentage of 6% (compared to 76% for "fresh” pulp). The imports themselves ended up mostly in the countries directly neighbouring Germany (Netherlands, Poland, France, Denmark, Switzerland, etc.) and only a small proportion travelled long distances.

System Description

Study Objective

This study aims to identify and compare the environmental impact of sulphate pulp, wastepaper pulp, and grass-based pulp. For illustration purposes and in order to facilitate comparison, a ton of paper produced in Germany is set as the reference figure.

Functional Unit

As a central element of ecological impact, the functional unit describes the value that the environmental effects of the raw material under consideration and its value-added chain relate back to.

In this study, this means that the quantity of each of the three different raw materials that is needed in order to produce a ton of paper in Germany will be taken as the base value. The specific inputs (energy, water, and chemicals) and outputs (wastewater, emissions, and waste) will all be calculated based on the quantity required to produce a ton of paper in Germany.

For sulphate pulp, the assumed quantities are 2.2 tons of wood, 1.25 tons of wastepaper, with an additional 5% sulphate pulp being added to the recycled paper mixture in keeping with standard production practices, and 1.07 tons of grass-based pulp.

System Limits and Methods

The system limits of an ecological impact analysis generally determine the sections of a value-added and process chain that are considered in the respective analysis. Additionally, it is also important to define which products, raw materials, and processes will be taken into consideration and the extent to which this consideration should be undertaken in regards to both time and space. A comparative ecological impact analysis was performed pursuant to ISO 14040. The inputs and outputs were included in the factual impact analysis within the context of the selected system limits also shown below. Wood-based pulp, wastepaper pulp, and grass-based pulp are at the heart of the investigation.

For wood-based pulp, sulphate pulp was chosen as the most important pulping process for obtaining pulp worldwide. In relation to sulphate pulp, it was possible to consider 95% of the sulphate pulp used for paper production in Germany as well as the starting materials. The steps taken between breaking down the raw material used for pulping and delivering the base material through to the producer were chosen as the system limits for modelling the value-added chain. Effects are determined exclusively for the categories of “Energy Consumption”, “Water Consumption”, “Greenhouse Gas Effect/CO_2 Emissions”, and “Acidification”.

For this case of comparative ecological impact, the system limits specifying which part of the value-added chain for paper manufacturing will be considered have been defined and the extent to which processes occurring upstream of the value-added chain will be included in the analysis has also been defined. The system limits will be described in detail over the course of the following process descriptions. One fundamental difference in the value-added chains of the raw materials being considered here is that the base materials for sulphate pulp and grass-based pulp are being derived for the first time, while this is not the case for wastepaper aside from the additional primary fibres. The wastepaper has already gone through one life cycle before being reused as recycled paper.

The system limits are generally set to include raw material harvesting processes, processing, treatment, transport, storage, and refinement to create the desired base material (the functional unit). This means that upstream steps such as planting/cultivation of the raw materials or creation of starting products are not considered, as is the case with the ecological cost of building the necessary infrastructure (e.g. ship building, road construction).

In order to take into account the peculiarity of wastepaper as a material, an assumption was also made. In defining the value-added chains of the sulphate pulp and wastepaper materials, the processes coming before this analysis were not considered. Rather, the actual (variable) uses within the value-added chains were considered.

Geographical Basis

For the sulphate pulp production process, wood harvesting, wood processing, and pulp production in the following countries and regions were taken into consideration: Germany, Finland, Sweden, Spain, Portugal, Brazil, Uruguay, Chile, and Eastern Europe.

Wastepaper is made mostly of base materials from Germany and the neighbouring countries such as the Netherlands, Poland, France, Denmark, and Switzerland. Only a very small portion of wastepaper originated overseas.

Concerning grass-based pulp, it is assumed that the production process occurs within the borders of Baden-Württemberg (Swabian Alb) and is representative of Germany in terms of the technology used.

Time Frame

The years 2015 and 2016 are the referenced time frame for the considerations made here. This relates particularly to the quantification of the value-added chain under consideration based on the data of the Verband der Deutschen Papierindustrie, the World Trade Organization (WTO), and the Statistical Office of the European Union.

In regards to the environmental impact of technologies, older data is used that is derived from realistic utilisation of these technologies. Within the context of the comparative ecological impact analysis, it can thus be assumed that the machines used in the process are not always state-of-the-art.

Process Description

Sulphate Pulp

Within the context of comparative ecological impact, regions and countries of origination for the wood or pulp that were included in the analysis of ecological impact include the countries of origin of Scandinavia (Sweden, Finland), Southern Europe (Spain, Portugal), Latin America (Brazil, Chile, Uruguay), and finally Germany. The woods used included pine, spruce, eucalyptus, and other woods such as birch, which were used in much smaller quantities. A portion of these woods were exported to Germany from the region of origin in their raw form, while the other portion was processed to create sulphate pulp on-site. Only after it has been processed does this portion enter the German market as a base material for paper production. In the analysis, it was assumed that about 2.2 tons of wood are required on average in order to produce one ton of paper.

Felling, transport, sawing, woodchipping, and long-distance transport either to the local pulping factory or to Germany were included as part of the raw material retrieval process. Production of chlorine-free, bleached sulphate pulp encompasses wood treatment, chemical production, bleaching, drying, energy generation on-site, as well as treatment of the chemicals and wastewater. Materials are transported by road, railway, and sea.

In order to determine the respective inputs and outputs for a tone of paper, a so-called average tree (see Figure 1 for its composition) was defined whose composition corresponds to the distribution of woods used in the German paper industry to produce one ton of paper. Data from Eurostat, the World Trade Organisation (WTO) and the Verband Deutscher Papierfabriken was used for this purpose. The calculated and defined average tree weights 2.2 tons, has a volume of 3.3 cubic metres, is 49% from South America, 45% from Northern Europe, and 6% from Southern Europe as well as other countries.

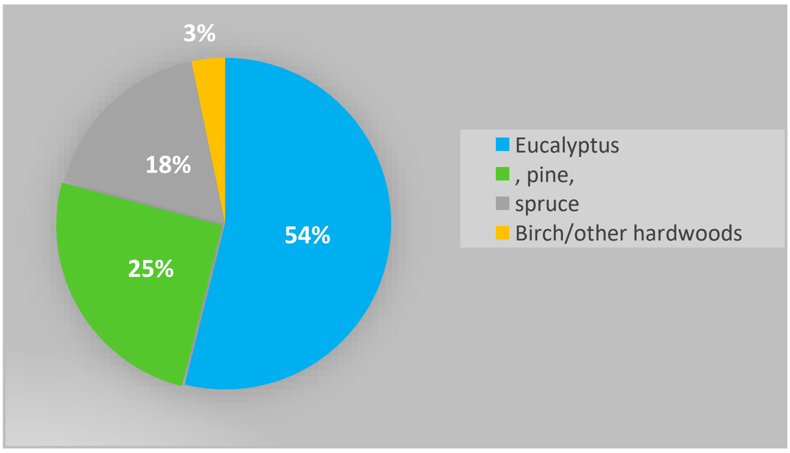


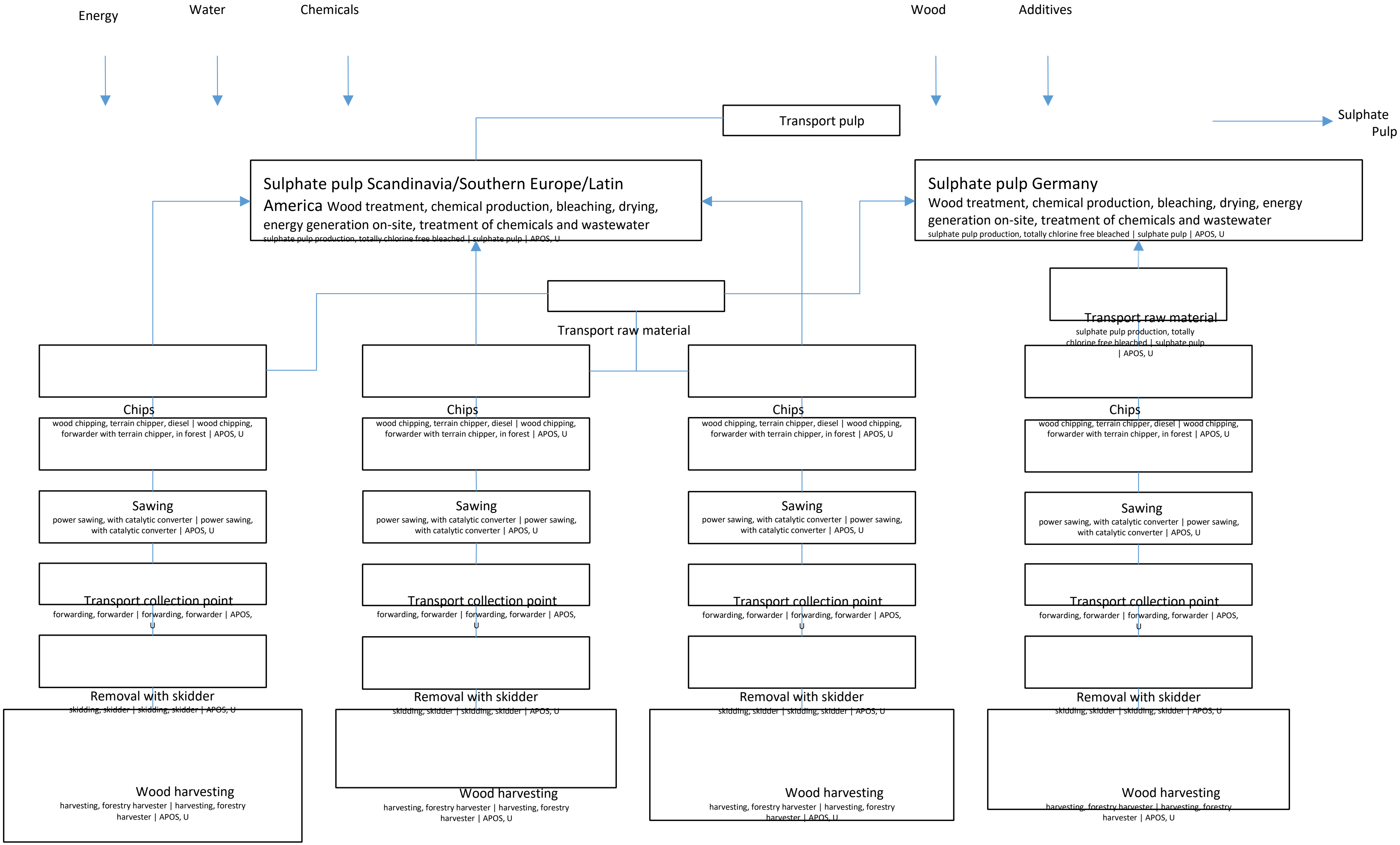
Figure 1: Composition of the average tree (illustration created for the study).

In the supply chain, the average tree is transported in the form of logs, woodchips, or pulp over an average distance of 13,000 kilometres. When broken down to correspond to one ton of paper, this amounts to a distance of 5,900 kilometres. The long distances are due in large part to the high quantity of imports from South America, with 10,175 kilometres being travelled by boat, 1,700 kilometres by train, and 1,150 kilometres by lorry.

The following assumptions were applied to calculate this transport distances: The length of transport distances by sea corresponds to the transport routes for bulk freighters between Hamburg (or Rostock for the Baltic Sea route) and the major foreign harbours in the vicinity of each of the major pulping factories. This yielded, for example, the freight ship route between Hamburg and Porto Alegre as the basis for calculations concerning the transport of pulp from Brazil. The exact values were calculated using the website www.searates.com. For lorry and train transport, average base values were used that take into account transport from the forest to the respective sawmill, to the pulping factory, to the corresponding harbour, and finally from the harbour to the paper factory in Germany.

For the pulp production processes and wood harvesting, it was assumed that the same technology is used in South America and Europe and that it is oriented on the volume of wood to be processed in each situation. The procedure for alkaline pulping using sulphates is such that the lignin found in the wood is extracted from the pulp (cellulose) using chemicals in a boiling chemical bath so that the pulp can be processed further. Following a rinsing process, the fibres are cut to the appropriate length, then fillers, paste, and dyes (such as kaolin, talcum, starch, calcium carbonate, and others) are added and it is dried following a draining process. In the last step, the base material is cut into sheets, tied up in bales, and transported to the paper factory.

The following Figure 2 contains the description of the value-added chain in graphic form as well as the data sets taken as the basis. The composition and processes contained in the data sets were modified to better reflect reality for the purposes of a comparative ecological impact analysis. It also contains information on which inputs were made into and which outputs came out of the illustrated product system for sulphate pulp.



Raw material harvesting Scandinavia

1) Pine: softwood forestry, pine, sustainable forest management | wood chips, wet, measured as dry mass | APOS, U – SE

2) Spruce: softwood forestry, spruce, sustainable forest management | wood chips, wet, measured as dry mass | APOS, U – SE

3) Birch: hardwood forestry, birch, sustainable forest management | wood chips, wet, measured as dry mass | APOS, U – SE

Raw material harvesting Southern Europe

1) Eucalyptus: hardwood forestry, eucalyptus ssp., sustainable forest management | roundwood, eucalyptus ssp. from sustainable forest management, under bark | APOS, U –

RoW

Raw material harvesting Latin America

1) Eucalyptus: hardwood forestry, eucalyptus ssp., sustainable forest management | roundwood, eucalyptus ssp. from sustainable forest management, under bark | APOS, U – RoW
2) Pine: softwood forestry, paraná pine, sustainable forest management | roundwood, paraná pine from sustainable forest management, under bark | APOS, U – RoW

Raw material harvesting Germany

1) Pine: softwood forestry, pine, sustainable forest management | wood chips, wet, measured as dry mass | APOS, U – SE
2) Spruce: softwood forestry, spruce, sustainable forest management | wood chips, wet, measured as dry mass | APOS, U – SE

Figure 1: Product system sulphate pulp (illustration created for study).

Emissions

Wastewat
er

Waste

Wastepaper

Behind China, the United States, and Japan, Germany is the country with the fourth-highest volume of wastepaper collected and used. In the year 2016, 16.9 million tons of wastepaper were used in Germany to make paper. This corresponded to a slight increase of 0.1% compared to the previous year and a proportion of use of 75% of all base materials used. In regards to foreign trade, 2.8 million tons of wastepaper were exported in 2016 and at the same time, 4.3 million tons of wastepaper were imported. The imported materials came mostly from Germany's neighbouring countries such as the Netherlands, Poland, and France and only a small portion of it travelled a far distance (e.g. from the United States). Competing with this is a volume of 12.5 million tons of wastepaper in Germany itself that was destined for domestic use.

Once the paper products in use exit their life cycle, the majority (75%) of wastepaper is collected, cleaned, de-inked, and processed to become a base material used to produce more paper later (see Fig. 3). During the de-inking process, printed inks are removed from the paper through either washing or flotation (using air) by applying chemicals (soaps and sodium silicate) in order to reclaim as high a percentage of pulp as possible for further use. A sieve process is then used to separate the remaining impurities from the pulp. This is where the process used to treat primary fibres (washing, cutting the fibres to length, mixing in filler, paste, and dyes, etc.) is applied.

It is generally assumed that 1.25 tons of wastepaper are required to produce one ton of recycled paper, with minimal material losses also being calculated in to account for the de-inking process described above. It is necessary to included calculations for material loss in this analysis, since the fibres involved in the de-inking process vary in length. Original primary fibres can be reused multiple times until the fibres eventually become too short, thus making them unsuitable for paper production.

This ultimately means that a calculated 5% sulphate pulp (as described above) must be mixed in for recycled paper production. Overall, the transport routes throughout the entire value-added chain globally, within Europe, and domestically are taken into consideration in turn. Calculations of the transport routes encompass wastepaper imports from eleven European countries as well as an approximation of the remaining import need.

Following transport and collection of wastepaper at the central collection points as well as sorting and cleaning in the wastepaper factory, it is considered wastepaper material after the de-inking process, during which old inks are chemically removed and pulp is extracted once more. Within the context of this comparative ecological impact analysis, the wastepaper material created is classified proportionately to the input used in manufacturing sulphate pulp and the output generated.

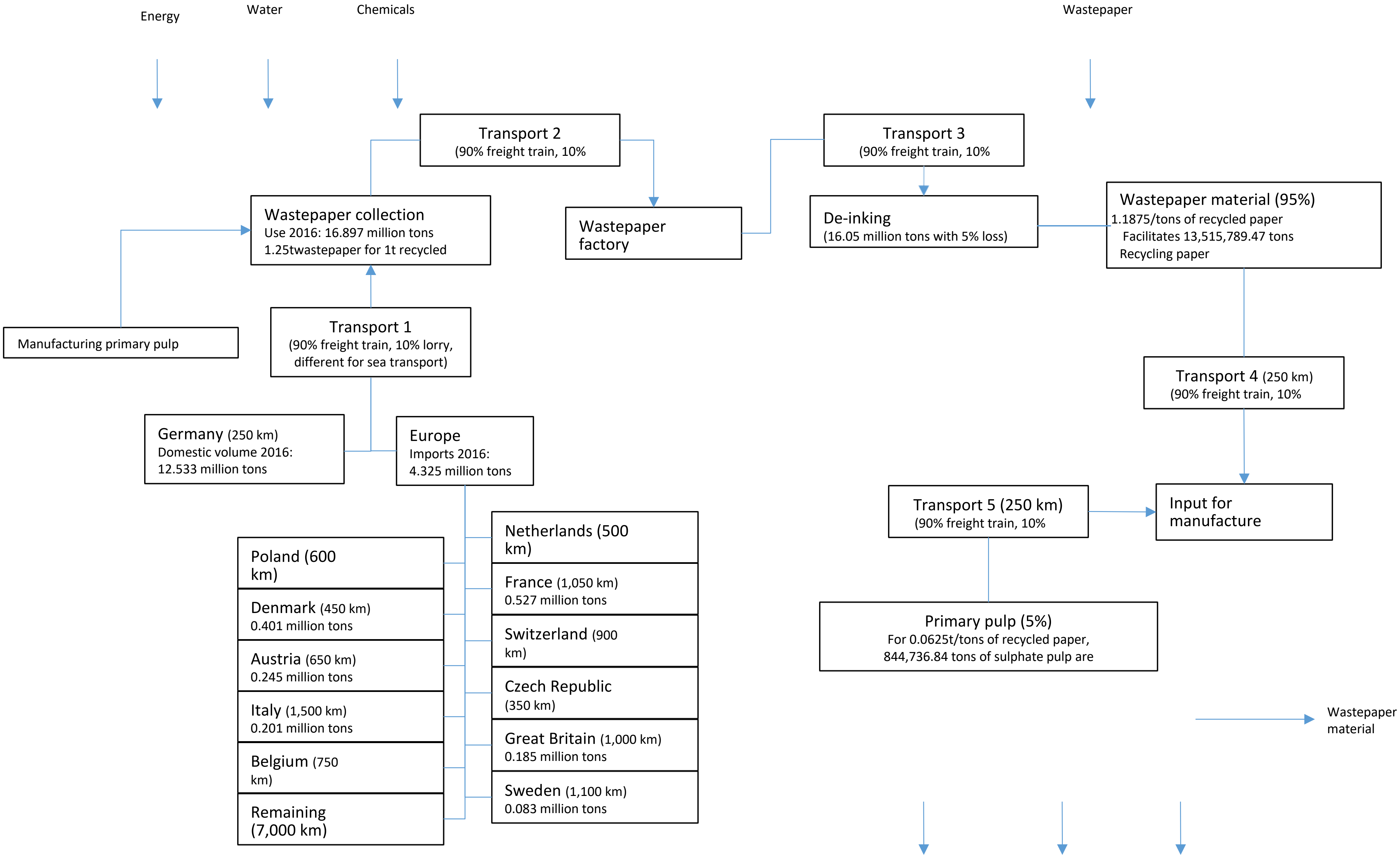


Figure 2: Wastepaper material product system (illustration created

for study).

Waste

Grass-Based Pulp

Alternative research on another base material for German paper production examined grass as a raw material. CREAPAPER obtains the raw material from an agricultural buffer area located no more than 50 km from the paper factory where the grass pellet machine is housed. Currently, CREAPAPER is harvesting the raw material from unused agricultural buffer areas in the Swabian Jura.

Within the context of the comparative ecological impact analysis, the yearly crop yield model was based on the assumption that an unfertilised field will yield an average yearly harvest (if mowed every six months) of five tons of dry matter per hectare. At the same time, this value also corresponds to the average harvest expected for a similar area in Germany. The mowing of the grass is coordinated either directly with the farmer as a contracted partner of CREAPAPER or by a responsible municipality.

Making use exclusively of agricultural buffer areas is the fundamental premise of CREAPAPER's business model. Furthermore, these buffer zones must also be located in the immediate vicinity (max. distance: 50 km) of the paper factory at which it will be processed in order to keep the necessary transport route as short as possible. In the calculation used here, the transport route is set to 100 km in order to leave room for deviations and empty trips (see Fig. 4). Vehicles with a total capacity of 20 tons are used for transport. The grass pellet machine the paper factory uses to convert grass into the necessary form is located on the factory premises, thus requiring little or no transport in the last step of production.

Obtaining the raw material of grass from a buffer area includes mowing, flipping (with an average drying time of four days and a maximum residual moisture of 14%), collecting, pressing into pellets, and then loading. This includes all transports from the field to the producer. In order to produce a ton of grass pellets, the grass pellet machine needs 134 kWh of energy and consumes two litres of water. This analysis assumes that the final paper product will consist 50% of grass pellets and 25% of primary pulp material (sulphate) and 25% wastepaper. As a result, 1.07 tons of grass pellets are required to produce one ton of grass-based paper.

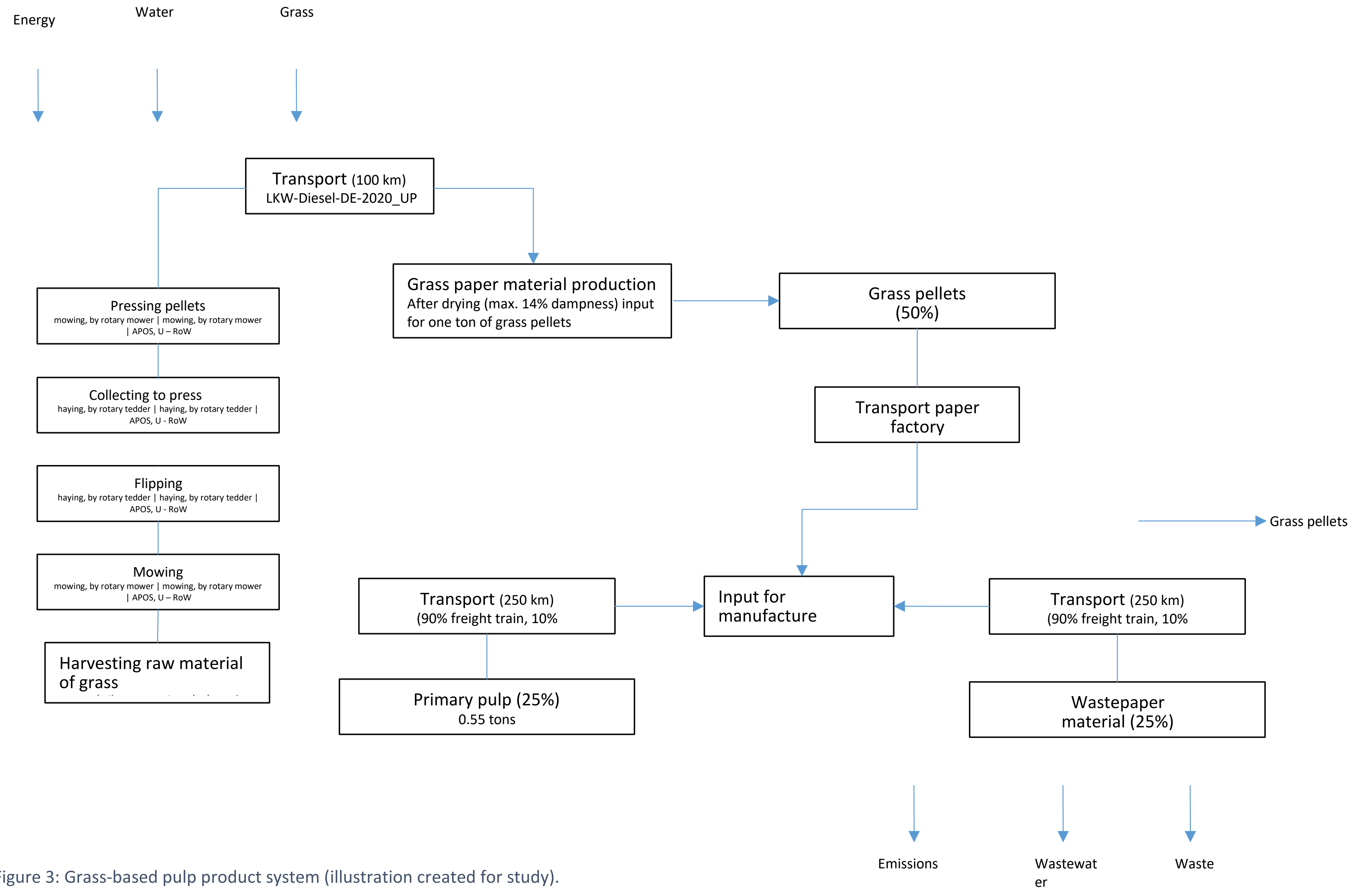


Figure 3: Grass-based pulp product system (illustration created for study).

Factual Analysis

Data Basis

Statistics from the Verband Deutscher Papierfabriken (VDP), the World Trade Organization (WTO), and the production statistics of the European Union (EuroStat) serve as the basis for qualitative and quantitative determinations made concerning the value-added chain of the sulphate pulp and wastepaper material used in Germany. Local conditions are estimated based particularly on the information provided by the pulp factories of Stendal and CREAPAPER GmbH (Germany) Asociacion Technica de la Celulosa y el Papel (Chile), StoraEnso (Finland), Skogsindustrierna (Sweden), Bradesco Departamento de Pesquisas e Estudos Econômicos, eucalyptus.com.br (Brazil), American Forest & Paper Association, Wood Resources International (USA). The ecological impact is estimated specifically based on the databases “ecoinvent v3.3” (Status 2017) and the
“Process-Oriented Basic Data for Environmental Management Instruments (ProBas)” of the German Environmental Agency (Status 2015).

Impact Categories

We included the following four impact categories in our analysis:

- Anthropogenic greenhouse gas effect
- Acidification
- Energy consumption
- Water consumption

Anthropogenic Greenhouse Gas Effect

In the ecological impact analysis, the additional warming of the earth caused by the emission of gases by people and beyond the natural greenhouse gas effect is referred to as anthropogenic greenhouse gas effect. The additional increase in temperature was caused by the concentration of these gases in the troposphere. Individual gases show different levels of impact in the troposphere and this is referred to in a simplified manner as carbon dioxide equivalence or greenhouse warming potential: This gives a factor by which the presumed effect of the emitted mass of a gas is stronger compared to the same emitted mass of carbon dioxide on the greenhouse warming potential. The following table shows the gases considered here in order to determine the greenhouse warming potential as well as its presumed carbon dioxide equivalent.

Gas	Carbon dioxide equivalence factor
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	300

Acidification

The term "acidification" encompasses the decline in the pH value of the ground and nutrient-poor bodies of water as well as vegetation damages resulting directly or indirectly from the emission of gases by people. One of the main causes of declines in pH values is acid rain, which in turn is connected to air pollution. To be specific, sulphur is released into the atmosphere when something is burned and is brought back to earth by rain in the form of acid containing sulphur. Over-fertilisation will also result in excess nitrates being washed out of the ground by water (alkaline leaching). The acidification potential from emissions is measured by sulphur dioxide equivalents. This gives the factor of how much stronger the presumed effect of the determined mass of a gas has on acidification compared to the same defined mass of sulphur oxide. The following emissions were included in our analysis:

Gas	Sulphur oxide equivalence factor
Sulphur oxide (SO_2)	1
Nitrogen oxide	0.7
Ammonium	1.88

Energy consumption

The energy consumption of a production process is determined on the one hand by the fuel value for the energy source used in the machine and on the other hand by the output of devices run using electricity.

Water Consumption

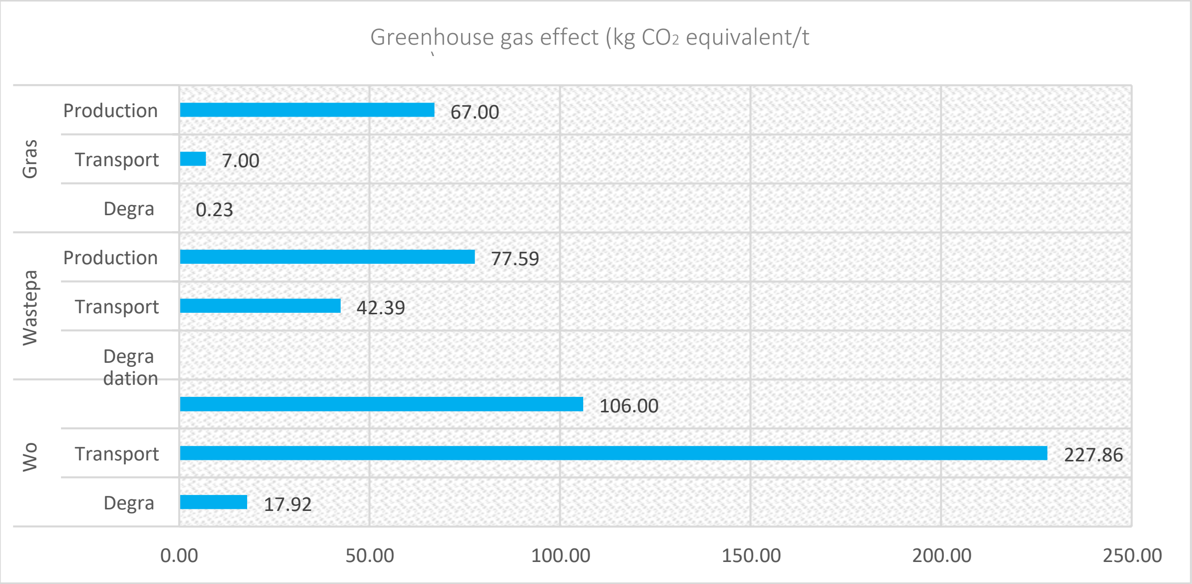
The water consumption considered here is a direct result of pulp production for further processing to create paper products. Water consumption for other process steps, cooling water for machines for example, was not considered.

Handling Uncertainty

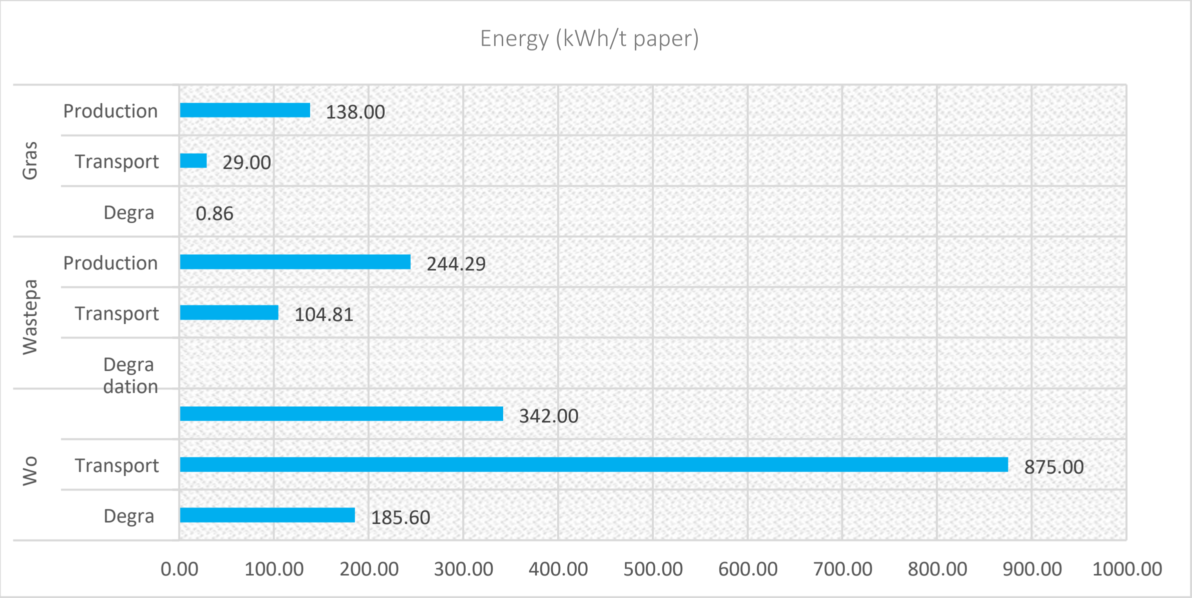
The estimation of impact for a value-added chain is yielded from the sum of its processes. The data for the individual processes is often based on varied assumptions and was often collected at different times, at different locations, and with varying levels of detail. As a result of this, it is often relatively difficult to compare information on the environmental behaviour of individual processes and this generally requires a plausibility check. In order to protect the integrity of the comparisons in this study as well as possible, only emissions and environmental impacts that could be selectively and precisely derived from all processes considered were included. For this reason, the comparative ecological impact analysis does not list information on further impact categories such as human toxicity or eutrophication. The study also refrains from making assumptions and attempting to approximate the impact of individual materials such as persistent synthetic chemicals.

Impact Assessment and Analysis

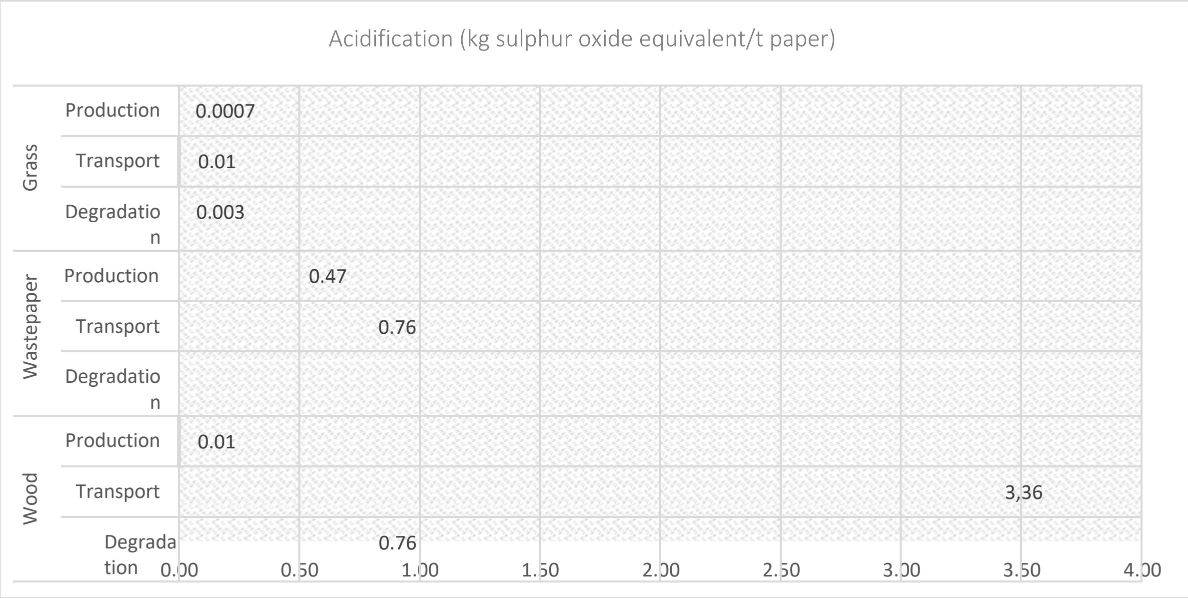
Greenhouse Gas Effect



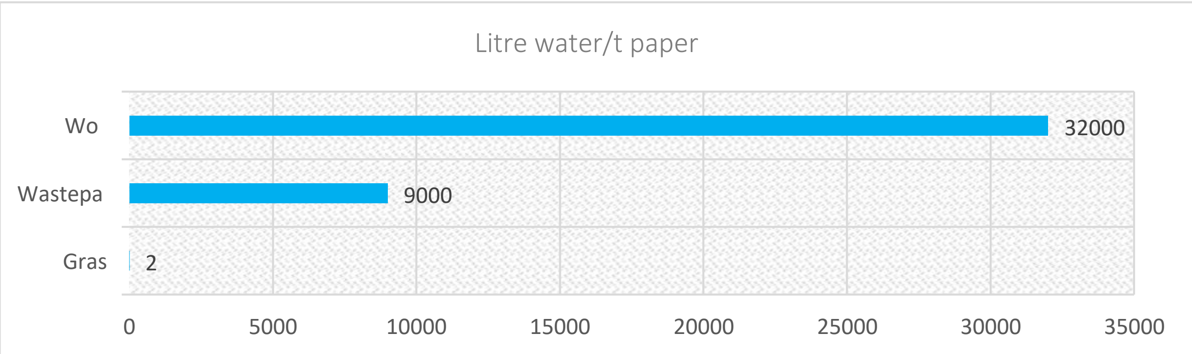
Energy Consumption



Acidification



Water Consumption



Conclusion

Summary

Within the context of the comparative ecological impact analysis, grass-based pulp performed considerably better than the alternative wood-based sulphate pulp and wastepaper pulp in regards to energy and water consumption, acidification potential, and emissions balance. This is because it was possible to obtain a similar volume of base material (at least 5 tons per year and hectare) from grass compared to wood harvesting. Only eucalyptus promises a considerably higher yield per year and hectare. There are reports of yields of up to 60 tons per year and hectare in Brazil.

Furthermore, the transport route, which was examined in detail during the course of this comparative ecological impact analysis, is a decisive factor in assessing the environmental impact. In order to use one ton of sulphate pulp in paper production, an average of 14,000 ton kilometres of pulp must be moved in the form of logs, woodchips, or refined pulp. One result gleaned from this is that the expenditures of energy and emissions for transporting one ton of sulphate pulp are higher than those for the entire production process for two tons of wastepaper material or three tons of grass-based pulp.

Over the past few years, the use of water in sulphate pulp production has decreased dramatically. All the same, in the scenario taken as the foundation for this study, water consumption remained at 32,000 litres per ton for sulphate pulp, 9,000 litres per ton for wastepaper material, and two litres per ton for grass-based pulp.

Relative Environmental Benefit of Grass-Based Pulp

Compared to the production of sulphate pulp and wastepaper pulp, grass-based pulp is considerably more environmentally friendly overall. Producing grass-based pulp is six times more energy-efficient than sulphate pulp, only generates 26% as many emissions, requires 16,000 times less water, and has an acidification potential 18 times lower.

Compared to wastepaper material, the production process for grass-based pulp is 1.5 times more energy-efficient, causes just 77% as many emissions, requires 4,500 times less water, and has an acidification potential that is 5 times lower.

Significance of Fuel and Energy Consumption for Ecological Impact of Pulp

Low fuel and energy usage in the production process, achieved particularly by shortening the transport routes, are decisive to the ecological advantage of grass-based paper. It will only be possible for grass-based pulp to maintain an ecological advantage of this magnitude if production is kept local and is done in buffer areas. If similar transport routes are used, grass-based pulp remains more environmentally friendly than sulphate pulp, but would no longer be more environmentally friendly than wastepaper material. At the same time, reducing the transport routes for sulphate pulp remains a hypothetical consideration, since the German pulp industry uses about 15 million trees each year, which it would be impossible to obtain locally.

Relative Environmental Advantage in Regards to Land Usage and Biodiversity

Beyond the ecological impact already described, grass-based pulp has another ecological advantage when it comes to land usage and transformation as well as interference with ecosystems and the associated impact on biodiversity.

Grass-based pulp is obtained from buffer areas and fallow land that is not cultivated specifically for this purpose. Furthermore, grass can also be cultivated and mowed on short notice in areas kept vacant due to legal requirements, as has been seen with the cultivation of elephant grass at the Amsterdam Schiphol Airport. Harvest cycles (every 6 months) are so short that it wouldn't be absolutely necessary to reserve space over a long period of time.

These time frames are longer for pulp obtained from wood. A single cycle for eucalyptus lasts seven years and at about fifteen years, it is even longer for European pine. Wood harvesting after such a long period is therefore connected with a decline in biodiversity, with an increased risk of soil erosion and possible changes in the microclimate. Mowing grass does not cause disadvantages of this magnitude and, if there are disadvantages, they are of a temporary nature.

Finally, despite the best efforts of the pulp industry and lawmakers, there is still the risk that illegally cut wood will make its way into the paper value-added chain, thus destroying protected natural spaces. This is not a risk for grass-based pulp.

Bibliography

Department for Research and Economic Studies (Departamento de Pesquisas e Estudos Econômicos – DEPEC)(2017): Papel e Celulose, Banco Bradesco, São Paulo, Brazil.

American Forest & Paper Association: Printing and Writing Papers Life-Cycle Assessment. Frequently Asked Questions, online at http://www.afandpa.org/docs/default-source/default-document-library/final-faq-document-12-3-10.pdf?sfvrsn=0 [18.09.2017].

Ansaharju, Aulis (2007): Paper, packing & forest products. Challenges for the Pulp and Paper Industry in Finland – Barnets Forest Forum, Joensuu, AA, Forest Forum/JW, hl, Stora Enso, Finland.

Couto, Laércio, Nicholas, Ian and Wright, Lynn (2011): Short Rotation Eucalypt Plantations for Energy in Brazil. Promising resources and systems for producing bioenergy feedstocks, IEA Bioenergy Task 43.

DIN German Institute for Standardisation (2006): Umweltmanagement – Ökobilanz – Anforderungen und Anleitungen (ISO 14044:2006), Beuth Verlag GmbH, Berlin.

DIN German Institute for Standardisation (2009): Umweltmanagement – Ökobilanz – Grundsätze und Rahmenbedingungen (ISO 14040:2006), Beuth Verlag GmbH, Berlin.

El Espectador (2014): Análisis de la producción de celulosa en Uruguay tras la apertura de la planta de Montes del Plata, in: El Espectador, vom 27.06.2014, online at http://www.espectador.com/economia/294215/analisis-de-la-produccion-de-celulosa-en-uruguay-tras-la-apertura-de-la-planta-de-montes-del-plata [18.09.2017].

Eucalyptus.com.br (2017): Eucalyptus Online Book, online athttp://www.eucalyptus.com.br/disponiveis.html [18/09/2017].

European Commission (2013): Characterisation factors of the LCD Recommended Life Cycle Impact Assessment methods. Database and supporting information, Joint Research Centre, Institute for Environment and Sustainability, EUR 25167 EN – 2012.

Happe, Barbara (2002): Der Kampf gegen die „Grüne Wüste". Brasilianische Zellstoffindustrie boomt auf Kosten von Mensch und Natur, ökozidjournal Nr. 23.

International Trade Centre [Intracen] (2017): Trade statistics for international business development, online at http://www.trademap.org [18.09.2017].

Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie (2011): Ermittlung von Erträgen auf dem Grünland. In Grünland Aktuell, April 2011.

Statistics Office of the European Union [Eurostat] (2017): Statistiken zur Produktion von Waren, online at http://ec.europa.eu/eurostat/de/web/prodcom/data/database [18.09.2017]

Swedish Forest Industries Federation: Pulp and Paper Industry, online athttp://www.forestindustries.se/forest-industry/statistics/pulp-and-paper-industry/ [18/09/2017].

Swedish Forest Industries Federation: Swedish Forests, online at http://www.forestindustries.se/forest-industry/statistics/swedish-forests/ [18.09.2017].

Verband Deutscher Papierfabriken e.V. (2017): Ein Leistungsbericht. Annual Report 2017.

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, B., 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230, online at http://link.springer.com/10.1007/s11367-016-1087-8 [18.09.2017].