Life Cycle Assessment

Of the stretch films DX and Doxess
By Doxa

Title: Life Cycle Assessment of DX and Doxess
Date: 04/06/2021
Report number: 822
Ordered by: Doxa
Issued by: Annie Johansson at Miljögiraff AB

MILJÖGIRAFF

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Ordered by: Doxa Plast i Värnamo AB

Doxa is a family-owned company that was founded in 1993 by Stig Claesson which still is the main owner together with his son John. The company has sales of approximately SEK 220 million, about 30 employees and a production facility in Värnamo.

We produce stretch film with a focus on thin film. Stretch film is a plastic foil that is used for packaging goods for safe transportation. Sustainability and circular solutions are the core of our product development. We are fast-paced and driven by commitment and innovation. Working with the highest quality products and having an environmentally friendly production is incredibly important to us, where we are at the forefront. All packaging film we produce is recyclable and we reuse 100 percent of all discarded material in production. We are a leading player in environmentally friendly plastic packaging – we stretch the possibilities!

Issued by: Miljögiraff AB

Miljögiraff is an environmental consultant specialised in Life Cycle Assessment and Ecodesign. We think that it is a combination of analysis and creativity needed to meet today's challenges. Therefore, we provide Life Cycle Analysis for the evaluation of environmental aspects and design methods for the development of sustainable solutions.

We create measurability in environmental work based on a life cycle perspective on environmental aspects. The LCA methodology establishes the basis for modelling complex systems of aspects with a credible assessment of potential environmental effects.

Miljögiraff is part of a global network of experts in sustainability metrics, piloted by PRé Sustainability.

Abbreviations and expressions

Clarification of expressions and abbreviations used in the report.

CO2eq – Carbon dioxide equivalents

EPD – Environmental Product Declaration

GWP – Global Warming Potential

ISO – International Organization for Standardization

LCA – Life Cycle Assessment

LCI – Life Cycle Inventory Analysis

LCIA – Life Cycle Impact Assessment

PCR - Product Category Rules

Environmental aspect - An activity that might contribute to an environmental effect, for example, “electricity usage”.

Environmental effect - An outcome that might influence the environment negatively (Environmental impact), for example, “Acidification”, “Eutrophication” or “Climate change”.

Environmental impact - The damage on a safeguarding object (i.e. human health, ecosystems, health and natural resources).

Life Cycle Inventory (LCI) data – Inventory of input and output flows for a product system

1 Introduction

The report presents the total environmental footprint for Doxa DX and Doxess produced by Doxa from a life cycle perspective using the ISO 14040 standard approach.

The purpose is to understand the environmental impact of Doxa DX and Doxess to find opportunities to mitigate the adverse effects and increase the potential contribution to sustainable development. The results of the study are also used for external marketing purposes.

Due to confidentiality regarding the recipes at Doxa, the LCI part as well as images in the results have been edited in this version of the LCA report.

1.1 Life Cycle Assessment

The importance of potential environmental impacts associated with the manufacturing and use of products is continuously increasing. A system perspective is required to find the best environmental strategy for product and business development. This has led to development of methods to better understand and address these impacts. One method is Life Cycle Assessment (LCA). It provides the backbone for strategies, management and communication of environmental issues related to products.

LCA can assist in;

- identifying opportunities to improve the environmental performance of products at various points in their life cycle,
- informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign),
- the selection of relevant indicators of environmental performance, including measurement techniques,
- marketing (e.g. implementing an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration).

Figure 1: The concept of Life Cycle Assessment.

LCA addresses the environmental aspects and potential environmental impacts) (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave), see Figure 1.

A major part of the environmental impact of a product depends on choices taken during the product development phase, e.g. materials, processes, functionality etc. The basic principles for abatement come from the discipline of cleaner technology, is defined in the concept of Integrated Product Policy (IPP) as:

> "All products cause environmental degradation in some way, whether from their manufacturing, use or disposal. LCA management seeks to minimise these by looking at all phases of a products' life-cycle and taking action where it is most effective.
> The life-cycle of a product is often long and complicated. It covers all the areas from the extraction of natural resources, through their design, manufacture, assembly, marketing, distribution, sale and use to their eventual disposal as waste. At the same time it also involves many different actors such as designers, industry, marketing people, retailers and consumers. LCA management attempts to stimulate each part of these individual phases to improve their environmental performance.
> With so many different products and actors there cannot be one simple policy measure for everything. Instead there are a whole variety of tools - both voluntary and mandatory - that can be used to achieve this objective."

Miljögiraff combines the confidence and objectiveness of the strong and accepted ISO standard, with the scientific and reliable LCI data from ecoinvent and with the world leading LCA software SimaPro for calculation and modeling (Figure 2).

Figure 2, ISO standard combined with reliable data from Ecoinvent and the LCA software SimaPro.

1.1.1 Limitations

The broad scope of analysing a whole life cycle of a product and the holistic approach can only be achieved at the expense of simplifying some aspects. Thus, the following limitations have to be taken into account as summarised by Guinée (Guinée, o.a., 2004):

- LCA does not address localised aspects, and it is not a local risk assessment tool
- LCA is typically a steady state, rather than a dynamic approach
- LCA does not include market mechanisms or secondary effects on technological development
- LCA regards processes as linear, both in the economy and in the environment

- LCA focuses on environmental aspects and says nothing on social, economic and other characteristics
- LCA involves several technical assumptions and value choices that are not purely science-based

1.2 ISO 14040

In 1997, the European Committee for Standardization published their first set of international guidelines for the performance of LCA. This ISO 14040 standard series has become widely accepted amongst the practitioners of LCA and is continuously being developed along with progressions within the field of LCA (Rebitzer et al. 2003). The guidelines for LCA are described in two documents; ISO 14040, that contains the main principles and structure for preforming an LCA, and ISO 14044, which includes detailed requirements and recommendations. Furthermore, a document containing the format for data-documentation (ISO/TS 14048), as well as technical reports with guidelines for the different stages of an LCA (ISO/TR 14049 and ISO/TR 14047), are available in this standard series. (Carlsson & Pålsson, 2011)

This LCA follow the “Book-keeping“ LCA approach which is defined as attributional LCA in the ISO 14040 standard.

The environmental management method Life Cycle Assessment (LCA) is used in this study. The LCA has been performed according to the ISO 14040 series standards.
ISO 14040: 2006 - Principles and framework
ISO 14042: 2006 - Life Cycle Impact assessment
ISO 14044: 2006 - Guiding

There are four phases in an LCA study; the goal and scope definition phase, the inventory analysis phase, the impact assessment phase and the interpretation phase. Below is a conceptual picture of this in Figure 3.

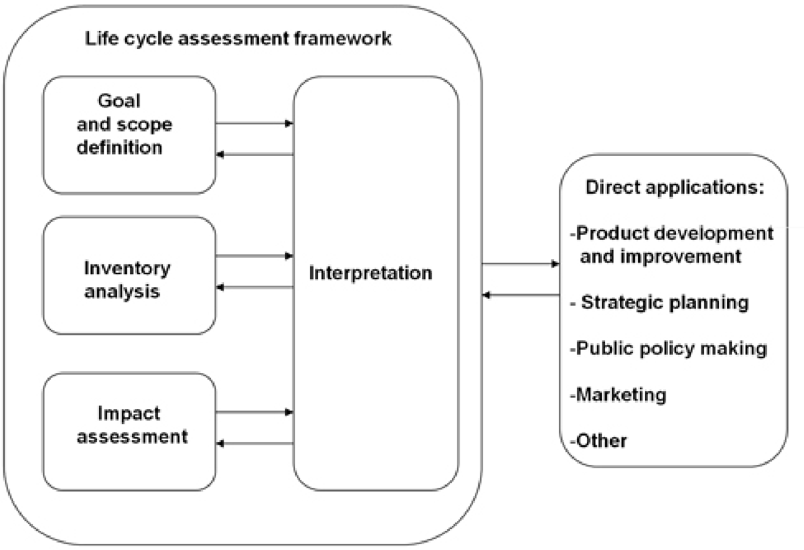


Figure 3. The four phases of the Life Cycle Assessment

1. The first phase is the definition of goal and scope. The goal and scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the

study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA.

2. The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study.

3. The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results so as to better understand their environmental significance.

4. Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

2 Goal and Scope

2.1 The aim of the study

The goal is to use the scientific method of Life Cycle Assessment to analyse the environmental impact of the products DX and Doxess produced by Doxa. The products will be investigated in different thicknesses as well as with different biobased content. The report shall describe the total environmental impact in an objective and fair manner, with clear connections between environmental aspects occurring in the life cycle and its associated environmental impacts. It shall also include recommendations for reducing the environmental impact.

The purpose of this LCA study is to use the objective and a complete picture of the environmental burden of the manufacturing of the two products to find opportunities for improving the environmental performance. Doxa are especially interested in the gaining an understanding of the impact from the products on the impact category climate change. The results will also be communicated externally business to business.

2.2 Scope of the Study

2.2.1 Name and Function of the Product/System

The scope of an LCA shall clearly specify the functions (performance characteristics) of the system being studied. The scope was from the cradle to the gate, that is all the way from the extraction of raw materials, transport of raw material and production of the product.

The products that are investigated in this report are the stretch films Doxa DX and Doxa Doxess. DX is a machine stretch film and Doxess is a hand stretch film. Doxa DX REBORN, which is a product with biobased content, is seen in Figure 4 below.

Figure 4 Doxa DX REBORN.

The product DX will be investigated in 3 versions, 100% fossil raw material, 50% fossil raw material and 10% fossil raw material. The product Doxess will be investigated in 2 versions, 100% fossil and 0% fossil raw material.

2.2.2 The Declared Unit and reference flow

The declared unit shall be consistent with the goal and scope of the study. One of the primary purposes of a declared unit is to provide a reference to which the input and output data are normalised.

The declared unit used in this report is 1 kg of material.

2.2.3 System Boundary

The system boundary determines which processes are included within the LCA. The selection of the system boundary shall be consistent with the goal of the study.

The deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study. Any decisions to skip life cycle stages, processes, inputs or outputs are clearly stated, and the reasons and implications for their exclusion are if any explained.

This study goes from cradle-to-gate. That means that all processes needed for raw material extraction, transport to manufacturing site and the manufacturing are included in the study. The cradle-to-gate system boundary is selected since Doxa wants to communicate their impact from cradle-to-gate in order for their customers to be able to use the results in further investigations of the life cycle until end product. The cradle-to-gate system boundary was also chosen since it, in a better way, highlights the possibilities to mitigate the environmental impact in the life cycle phases that Doxa can affect.

An overview of the system is seen in Figure 5 below. The raw materials in the illustration are the ones for DX with 50% biobased content.

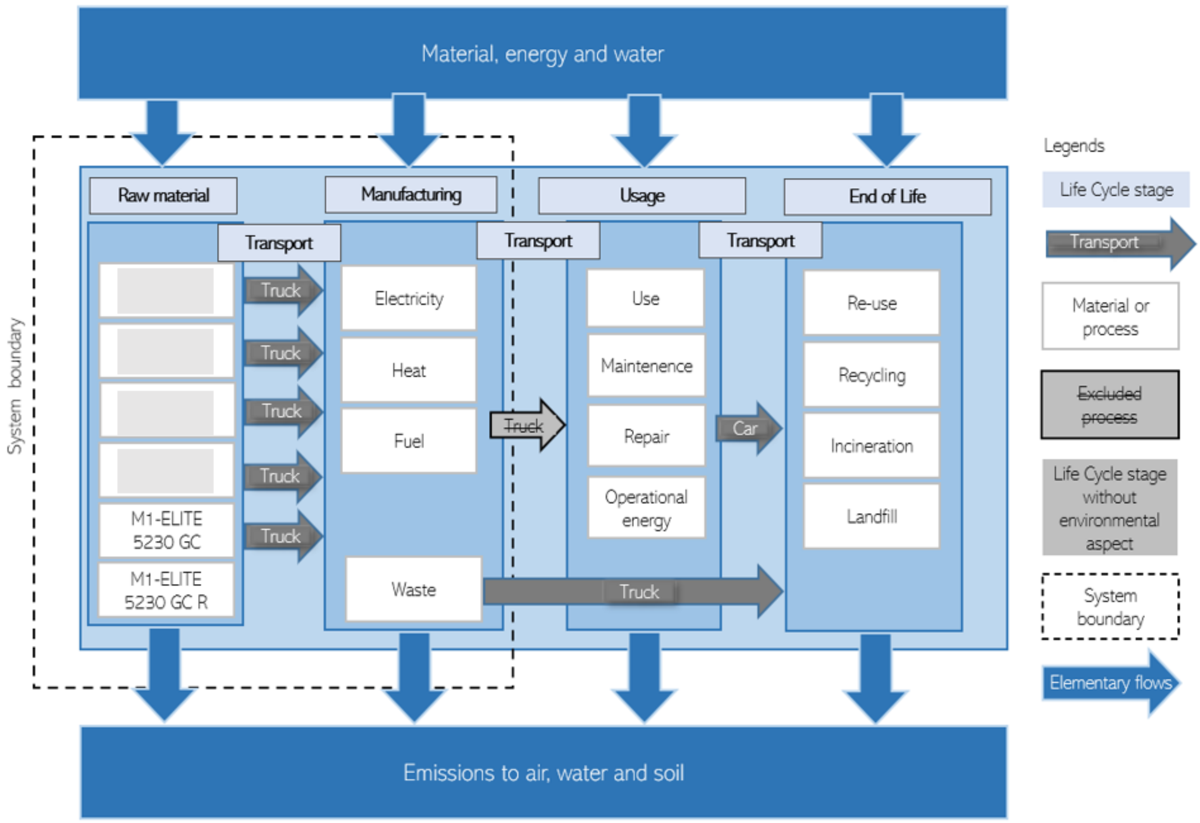


Figure 5. System boundaries for the model of the product system.

In this LCA, boundaries with other systems, and the allocation of environmental burdens between them, are based on the recommendations of the international EPD system[1], which are also in line with the requirements and guidelines of the ISO14040/14044 standards (IEC, 2008). In accordance with these recommendations, the Polluter Pays (PP) allocation method is applied. For allocation of environmental burdens when incinerating waste, this implies that all the processes in the waste treatment phase, including emissions from the incineration are allocated to the life cycle in which the waste is generated. Following procedures for refining of energy or materials used as the input in a following/receiving process, are allocated to the next life cycle.

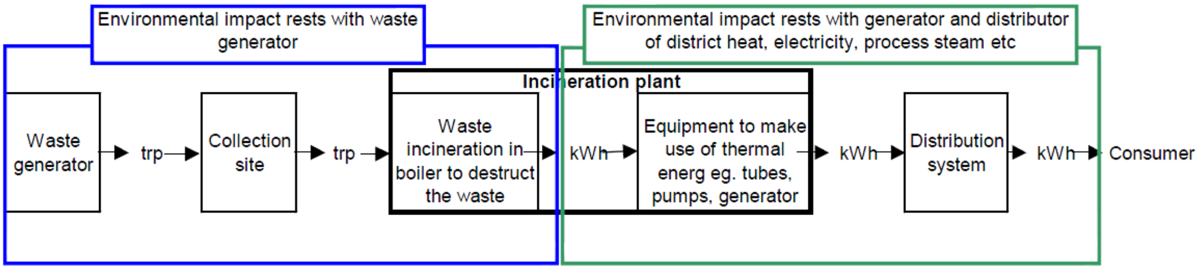


Figure 6: Allocation of environmental impacts between two life cycles according to the PP allocation method. Here in regard to incineration of waste and resulting energy products (Image from IEC, 2008, p14).

In the case of recycling, environmental burdens and potential benefits are accounted for outside of the generating life cycle and have thus been allocated to the subsequent life cycle which uses the recycled materials as input.

Avoided materials due to recycling have therefore not been considered in the main scenario. This in accordance to the ISO recommendations. In other words, only if the generating life cycle do use recycled material as input material will it account for the benefits of recycling.

2.2.4 Excluded parts and "cut-off"

A generic overview of processes that are included or excluded is presented in Table 1.

Table 1. Overview of aspects that are included or excluded.

Included	Excluded
Production of the raw materials and packaging materials.	Production of capital goods for manufacturing (machines and facilities)
Transport of components to manufacturing.	Transport of products to retail and to disposal.
Electricity and consumables used in the manufacturing	Disposal (in end-of-life)

The method chosen for the allocation is the cut-off method. The cut-off method assigns the loads caused by a product to just that product. When the cut-off method is used, environmental aspects or processes which can be assumed to contribute insignificantly do not have to be included in the study (Baumann & Tillman, 2004).

[1] EPD (Environmental Product Declarations) by the International EPD Cooperation (IEC)

It is common practice to scan for the most important factors ("cut off" at 95% as a minimum) rather than being very thorough. In general, LCA focuses on the most important flows, while the flows that can be considered negligible are excluded. By setting cut-off criteria specific and lower limit for the order of the flows to be included. Flows below the limit can be assumed to have a negligible impact and are thus excluded from the study. For example, cut off criteria can be determined for inflows with respect to mass or energy or outflows, e.g. waste.

To ensure that all relevant environmental impacts were represented in the study, the following cut-off criteria were used.

• Mass—If the flow was less than 1% of the cumulative mass of all the inputs and outputs of the LCI model, it was excluded, provided its environmental relevance was not a concern.

• Energy—If the flow was less than 1% of the cumulative energy of all the inputs and outputs of the LCI model, it was excluded, provided its environmental relevance was not a concern.

• Environmental relevance—If the flow met the above criteria for exclusion yet was thought to have a potentially significant environmental impact. It was evaluated with proxies identified by chemical and material experts within Miljögiraff. If the proxy for an excluded material had a significant contribution to the overall LCIA, more information was collected and evaluated in the system.

The sum of the neglected material flows did not exceed 5% of mass or 1% of energy.

2.2.5 Allocation

The inputs and outputs shall be allocated to the different products according to clearly stated procedures that shall be documented and explained together with the allocation procedure.
The sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation.

Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach.

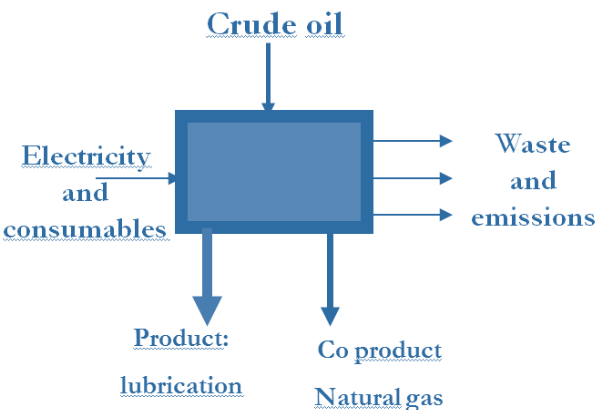


Figure 7: Allocation example,

Allocation of environmental aspects may occur when a process produces more than one product. The basis for this allocation is primarily economic value, secondarily physical properties. If the allocation has low importance, it may be "cut-off", not considered. Instead, all load is on the studied product.
The method chosen for the allocation is the cut-off method. The cut-off method assigns the loads caused by a product to just that product. When the cut-off method is used, environmental aspects or processes which can be assumed to contribute less than 1 %, do not have to be included in the study (Baumann & Tillman, 2004).

2.2.6 Allocation procedure

The study shall identify the processes shared with other product systems and deal with them according to the stepwise procedure presented below:

Step 1: Wherever possible, the allocation should be avoided by dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes or expanding the product system to include the additional functions related to the co-products.
Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.
Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

In this assessment, an economic allocation is done as far as possible. When other allocations are used, it is expressed if it may be significant to the results. Allocation of waste is described in ISO 14044 section 4.3.4.3.3 (ISO, 2006).

Waste is allocated in accordance with the method Allocation cut-off by classification in accordance with EPD guidelines (The International EPD® System, 2015). In this study, there has been no environmental aspects to apply the method to.

2.2.7 Method of Life Cycle Impact Assessment (LCIA)

The LCIA methods are chosen to give a comprehensive and multifaceted picture of the environmental effects of the different materials life cycle. In total, 11 different environmental effect categories will be used to give a different perspective on the environmental burden.

The life cycle impact assessment (LCIA) was made with the LCA-software SimaPro 9. In this software, databases with generic LCI data and a number of readymade LCIA-methods are included. All these are well recognised scientific methods. The impact categories and indicators and the method used in this study are listed in chapter 4.1 Method for impact assessment.

The **CML**[2] method was chosen for this study because it is the most recently updated, the most comprehensive and the best adapted to all the environmental effects that are relevant for this study. More information on the CML method can be found in Appendix 1.

This is a well-recognised scientific method.

The life cycle impact assessment (LCIA) was made with the LCA-software SimaPro[3]. In this software, databases with generic LCI data (i.e. ecoinvent[4]) and several readymade LCIA-methods are included. The impact categories, category indicators and characterisation models used are determined by the demands stated in ISO 14040 (2006a).

Table 2. Impact categories and indicators used in the study.

Impact category name	Category indicator
Resource use, mineral and metals	kg Sb eq
Resource use, energy carriers	MJ

[2] CML-IA Baseline v4.7
[3] Version 9.1.1.1 described at support.simapro.com.
[4] ecoinvent v3.5

Climate change	kg CO2 eq
Ozone layer depletion	kg CFC11 eq
Human toxicity	kg 1,4-DB eq
Freshwater aquatic ecotoxicity	kg 1,4-DB eq
Marine aquatic ecotoxicity	kg 1,4-DB eq
Terrestrial ecotoxicity	kg 1,4-DB eq
Photochemical oxidation	kg C2H4 eq
Acidification	kg SO2 eq
Eutrophication	kg PO4 eq

2.2.8 LCA Software

The software SimaPro 9.1 was used during the completion of this study.

SimaPro, developed by PRé Consultants, is the world's leading LCA software chosen by industry, research institutes and consultants in more than 80 countries. SimaPro is a powerful tool for calculations of complex product systems and in-depth comparisons of life cycles with documentation that conform to the ISO 14000 standard.

2.2.9 Interpretation

Interpretation of the results are made by identifying the data elements that contribute significantly to each impact category, evaluating the sensitivity of these significant data elements, assessing the completeness and consistency of the study, and drawing conclusions and recommendations based on a clear understanding of how the LCA was conducted and the results were developed.

2.2.10 Data requirements

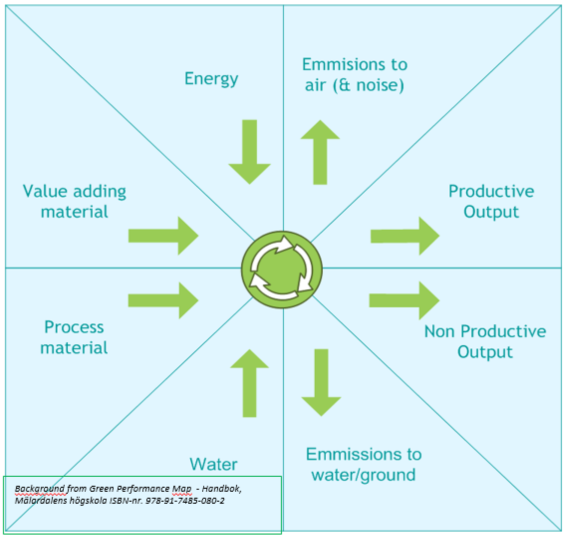
The manufacturing stage will be represented with specific data. That means that all data concerning material, energy and waste are specifically modelled for the prerequisites of the manufacturing facility and the technology that are used. Data concerning raw material suppliers will be regionalised depending on the country or geographical region the supplier comes from.

For the other life cycle stages, general data is used. General data means that material or energy are represented using average LCI data from ecoinvent 3.6.

The following requirements are used (see below) for all LCI data.

Time period: 2014 and after
Geography: Europe, Western
Technology: Average technology
Representativeness: Average from a specific process
Multiple output allocation: Physical causality
Substitution allocation: Not applicable
Waste treatment allocation: Not applicable
Cut-off rules: Less than 1% environmental relevance
System boundary: Second order (material/energy flows including operations)
The boundary with nature: Agricultural production is part of the production system

The level of depth depends on the availability of inventory data. By using general data from certified organisations, the fidelity and amount of Life Cycle Inventory (LCI) data increase very much. It is crucial, however, to understand those specific producers may differ significantly from general practice and average data.



1. raw material
2. energy
3. releases to air and noise
4. products
5. Ancillary materials
6. Water
7. releases to water and soil
8. co-products and waste

Figure 8 Environmental System Analysis as standard for data to be collected.

2.2.11 Data quality and representativeness

Different types of data are used throughout the study depending on availability of information and quality of data.

Specific data
1. Environmental Product Declarations (type III)
2. Collected data (webformat, site visits and interviews).
3. Reported data (EMS, Internal data systems or spread sheats)

Selected generic data
1. Close proxy with data on similar product
2. Statistics
3. Public documents

Generic data
1. Public and verified libraries with LCI data
2. Trade organisations libraries with LCI data
3. Sector based IO data, national

Both the data quality and the representativeness of the data are important to fulfil the goal and scope of the study. All data for the production has been collected from Doxa and is representative of the production practices under 2020. In the cases where no specific data could be used, available generic data was used mainly provided by ecoinvent 3.6 (2019).

Generic data was also used for the transportation of raw material, however, distance and information regarding the type of transportation was collected from Doxa. Further description of the data collected and used for the study is presented in chapter 3 (Life cycle inventory analysis). The data sources chosen to model the system were chosen as they were considered the best available data. The assessment of data quality and representativeness is summarized in Table 3.

Table 3 Data quality assessment for the study.

Aspect	Notes
Data quality assessment scheme	The data quality level and criteria from the PEF category rules has been applied in this study
Geographical coverage	Upstream data: Good Core module: Very good (site-specific)
Technological representativeness	Upstream data: Good (Specific and generic data based on plant averages) Core module: Very good (site-specific)
Time-related coverage	Upstream data: Good Core module: Very good (2020 data)
Validity	The technological and geographical coverage of the data chosen reflect the physical reality of the product system modelled.
Plausibility	The data used for the core process and some upstream processes have been checked for plausibility.
Precision	Material and energy flows quantified based on generic data from the ecoinvent 3.6 database.
Completeness	Data accounts for all known sub-processes. All upstream processes were modelled using generic data from the ecoinvent 3.6 database, using country-specific datasets whenever available, otherwise using European datasets.
Consistency, allocation method, etc.	Allocation follows a physical causality in line with ISO 14044.
Completeness and treatment of missing data	No data is found missing.
Final result of data quality assessment	Data quality as required in ISO 14044 is met.

2.2.12 Assumptions

Assumptions that are general to the entire LCA are:
• choice of energy model: (e.g. regional averages obtained from the Ecoinvent LCI database or according to specific conditions);
• choice of transport model: (e.g. regional averages from Ecoinvent (Michael Spielmann, Christian Bauer, Roberto Dones & Matthias Tuchsmid, 2007)or according to specific conditions calculated according to the Network for Transport and the Environment (NTM).
• EcoInvent processes that contain market funds such as “Diesel burned in building machine {GLO} | market for | Cut-off, U ”contains generic shipments from producer to end customer. Therefore, these data sets have no further transport.

Specific assumptions are presented in the section for the life cycle inventory, see section 4, Inventory of environmental aspects (LCI).

2.2.13 Type of critical review, if any

A critical review was carried out according to the International Standards ISO 14040 and 14044 (International Organization for Standardization (ISO) 2006a, b) by a third-party verifier, Martyna Mikusinska from Sweco. After the review was completed, the verifier created Verification report 1 in which the review comments are documented. This report was sent to the LCA practitioner at Miljögiraff, and the LCA report was adjusted according to the comments and suggested adjustments in the Verification 1 report. The revised LCA report and the responses to the review comments was returned to the reviewer, whereby the review report was updated and saved as Verification report 2. The Verification 2 report was attached as an appendix to the final version of this LCA report in order to ensure transparency.

3 Life cycle inventory (LCI)

In the inventory analysis, the product system is defined and described. At first, the material flows and relevant processes required to the product system are identified. Secondly, environmentally relevant data, (i.e. resource inputs) emissions and product outputs for the system components are collected and interpreted.

Data have been provided by Doxa (Vesterlund, 2020) unless otherwise stated.

Due to confidentiality regarding the recipes at Doxa, the LCI part has been edited in this version of the LCA report.

3.1 DX

This part describes the LCI data in the different life cycles of the product DX from Doxa.

3.1.1 Raw material for 1 kg DX 50% biobased M1-ELITE 5230

This part describes all the different raw material needed for the manufacturing of 1 kg of Doxa DX with 50% biobased content. In Table 4 below, the raw materials needed for 1kg DX with 50% biobased content are presented with description of LCI data in ecoinvent.

Table 4 Raw material for DX 20 micron and the description of LCI data in ecoinvent.

Raw material	Kg /kg DX	Description of LCI data in ecoinvent
LLDPE	confidential	Polyethylene, linear low density, granulate {RER}| production | Cut-off, U
LLDPE	confidential	Polyethylene, linear low density, granulate {RER}| production | Cut-off, U
confidential	confidential	confidential
confidential	confidential	confidential
LLDPE (M1-ELITE 5230GC)	confidential	See 3.1.1.1
LLDPE (M1-ELITE 5230GC R)	confidential	See 3.1.1.1

3.1.1.1 LLDPE M1-ELITE 5030GC & LLDPE M1-ELITE 5030GC R

The raw material is produced by Dow in the Netherlands. The bio-naphta, used by Dow for the biobased PE is produced by UPM in Finland. The results calculated using the CML method are provided by Dow (Helling, R., 2020).

Table 5 Data for LLDPE M1-ELITE 5030GC & LLDPE M1-ELITE 5030GC R, supplied by Dow.

Impact category	Unit	Elite 5230 PE production from bio-naphtha in Terneuzen, 86% bio-C	Elite 5230 PE production in Terneuzen, 100% fossil C
Abiotic depletion	kg Sb eq	5.42E-07	1.18E-06
Abiotic depletion (fossil fuels)	MJ	3.68E+01	7.37E+01
Global warming (GWP100a)	kg CO2 eq	1.91E+00	1.68E+00

Ozone layer depletion (ODP)	kg CFC-11 eq	2.16E-07	4.64E-07
Human toxicity	kg 1,4-DB eq	1.06E-01	3.39E-01
Fresh water aquatic ecotox.	kg 1,4-DB eq	6.92E-02	1.83E-01
Marine aquatic ecotoxicity	kg 1,4-DB eq	1.95E+02	5.49E+02
Terrestrial ecotoxicity	kg 1,4-DB eq	7.09E-04	7.16E-04
Photochemical oxidation	kg C2H4 eq	2.61E-04	3.78E-04
Acidification	kg SO2 eq	2.64E-03	5.06E-03
Eutrophication	kg PO4--- eq	4.64E-04	6.96E-04

3.1.2 Raw material - DX 0% biobased M1-ELITE 5230

This part describes all the different raw material needed for the manufacturing of 1 kg Doxa DX with 100 % fossil content.

Table 6 Raw materials for 1 kg of DX with 100% fossil M1-ELITE 5230.

Raw material	Kg/kg
LLDPE	confidential
LLDPE	confidential
confidential	confidential
confidential	confidential
LLDPE (M1-ELITE 5230GC)	0.838

3.1.3 Raw material - DX 100% biobased M1-ELITE 5230

This part describes all the different raw material needed for the manufacturing of 1 kg Doxa DX with 100% M1-ELITE 5230 from tall oil.

Table 7 Raw material for DX 100% biobased M1-ELITE 5230.

Raw material	Kg/kg
LLDPE	confidential
LLDPE	confidential
confidential	confidential
confidential	confidential
LLDPE (M1-ELITE 5230GC R)	0.838

3.1.4 Transport of raw material - DX

The raw material is transported from the suppliers to Doxa in Värnamo, Sweden, by truck. The supplier and transport distances are presented in Table 8.

Table 8 Transport of raw materials for DX from suppliers to Doxa.

Raw material	Transport distance	Supplier / location	Description of LCI data in ecoinvent
LLDPE	927 km	confidential	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U
LLDPE	1328 km	confidential	Same as for LLDPE
confidential	927 km	confidential	Same as for LLDPE
confidential	1707 km	confidential	Same as for LLDPE
LLDPE (M1-ELITE 5230GC)	2501 km	Dow / Spain	Same as for LLDPE
LLDPE (M1-ELITE 5230GC R)	2501 km	Dow / Spain	Same as for LLDPE

3.1.4.1 Transport of packaging material - DX

The supplier and transport distances of the packaging material used by Doxa for the finished product is presented in Table 9 below.

Table 9 Transport of packaging materials to Doxa.

Raw material	Transport distance	Supplier / location	Description of LCI data in ecoinvent
Bobbin	284 km	Corex / Sweden	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U
HD bottom sheet	30 km	Draken / Sweden	Same as for Bobbin
HD top sheet	30 km	Draken / Sweden	Same as for Bobbin
EURO pallet	49 km	Erico / Sweden	Same as for Bobbin
Stretch film (DX 23 micron, 50% biobased)	0 km	Doxa / Sweden	Same as for Bobbin

3.1.5 Manufacturing of DX at Doxa

Doxa DX is manufactured in Värnamo, Sweden. The raw material arrives by truck to Doxa's production facility in Värnamo. The truck loads the material into silos.

When the product is to be made in the cast line, the material travels in pipes from the storage location. In the cast line the material blends and gets divided into different layers. The layers pass a feedblock before it melts down on the chill roll. After the chill roll the material gets rolled up on cores in the winder. The process from the winder to fully packed pallet is fully automatic and robotized.

In the manufacturing process at Doxa 0.750 kWh of electricity are used per 1kg of DX. The electricity comes from 100% renewable energy by hydro power in Sweden, certificate according to GoO (Guarantee of Origin) can be seen in Appendix 4. The electricity is represented by the dataset *Electricity, high voltage {SE}| electricity production, hydro, run-of-river | Cut-off, U* in ecoinvent.

The manufacturing process generates 0.816 kWh of excess heat per kg of DX. The heat is transferred to the local district heating grid. Benefits from the excess heat in the district heat is allocated to the life cycle of the district heating.

The consumables used in the manufacturing at Doxa are specified in

Table 10 below.

Table 10 Consumables at Doxa

Consumable	Amount per m2 DX	Name of supplier	Description of LCI data in ecoinvent
Grease	5.02E-04	Industrishopen	Lubricating oil {RER}| market for lubricating oil | Cut-off, U
Silicon spray	2.01E-05	Smartab	Lubricating oil {RER}| market for lubricating oil | Cut-off, U
Methylated spirit	2.01E-05	Swedol	Solvent for paint {GLO}| white spirit to generic market for solvent for paint | Cut-off, U

No emissions are generated in the manufacturing processes at Doxa.

The water used in the process for cooling is in a closed system. The consumption per kg finished product falls under the cut-off.

In the manufacturing 3% of waste occurs for the products. This waste is recycled inhouse at Doxa.

The internal transports on site corresponds to the finished products being loaded on a truck and being transported to the warehouse. The transport distance is 8 km.

3.1.6 Packaging of DX

The product is packaged with a bobbin, top sheet and bottom sheet, wrapped with stretch film and put on a wooden pallet. The packaging materials for DX micron are presented in Table 11.

Table 11 Packaging materials used for the finished product DX.

Packaging material	Kg/kg	Description of LCI data in ecoinvent
Bobbin	0.0606	See 3.1.6.1 Bobbin below
HD bottenark	0.000150	Polyethylene, low density, granulate {RER}| production | Cut-off, U

HD toppark	0.000150	Polyethylene, low density, granulate {RER}| production | Cut-off, U
EURO pallet	0.0505	EUR-flat pallet {RER}| production | Cut-off, U
Stretch film (DX, 50% biobased)	0.000364	See data for DX

3.1.6.1 Bobbin

The bobbin is made from recycled well fibers. It will be represented by the dataset Corrugated board box {RER}| production | Cut-off, U with modified electricity and input. The electricity is modified to Swedish electricity and the input of containerboard is replaced with *Waste paper, sorted {Europe without Switzerland}| treatment of waste paper, unsorted, sorting | Cut-off, U*. Furthermore, the input waste paperboard is removed from the original dataset.

3.2 Doxess

For Doxess there are two versions, 100% fossil content or a recipe with 100% M1-ELITE 5230 from tall oil. The weight of the raw materials per kg of Doxess for each version is presented in the tables below.

3.2.1 Raw material – Doxess with 0% biobased M1-ELITE 5230

In the table below the raw materials needed for Doxess with 100% fossil content.

Table 12 The raw materials for the Doxess products with 0% biobased M1-ELITE 5230 and their description of LCI data in ecoinvent.

Raw material	Kg/kg	Description of LCI data in ecoinvent
LLDPE	confidential	See 3.1.1
confidential	confidential	confidential
confidential	confidential	confidential
M1-ELITE 5230GC	confidential	See 3.1.1.1

3.2.2 Raw material – Doxess with 100% biobased M1-ELITE 5230

In the table below the raw materials needed for Doxess with 100% M1-ELITE 5230 from tall oil.

Table 13 The raw materials for the Doxess products with 100% M1-ELITE 5230 from tall oil and their description of LCI data in ecoinvent.

Raw material	Kg/kg	Description of LCI data in ecoinvent
LLDPE (FR)	confidential	See 3.1.1
confidential	confidential	confidential
confidential	confidential	confidential
M1-ELITE 5230GC R	confidential	See 3.1.1.1

3.2.3 Transport of raw materials

The supplier and transport distances of the raw materials used for Doxess is presented in Table 14 below.

Table 14 Transport of raw materials for Doxess from suppliers to Doxa.

Raw material	Transport distance	Supplier / location	Description of LCI data in ecoinvent
LLDPE	1328 km	confidential	Same as for LLDPE in DX
confidential	1707 km	confidential	Same as for LLDPE
confidential	9649 km	confidential	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, U
	168 km	confidential	Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Cut-off, U
LLDPE (M1-ELITE 5230GC)	2501 km	Dow / Spain	Same as for LLDPE
LLDPE (M1-ELITE 5230GC R)	2501 km	Dow / Spain	Same as for LLDPE

The transport from Sasol is assumed to be by ship from the port in Houston to the port in Gothenburg, 5210 nautical miles, and then by truck from Gothenburg to Doxa in Värnamo.

3.2.4 Transport of packaging materials

The same packaging materials are used for Doxess as for DX. The transport distances for the packaging materials can be found in
Table 9.

3.2.5 Manufacturing

The manufacturing process for Doxess is the same per kg as for DX. For details see 3.1.5 Manufacturing of DX at Doxa.

3.2.6 Packaging

The product is packaged with a bobbin, top sheet and bottom sheet, wrapped with stretch film and put on a wooden pallet. The amount of packaging material for each thickness of Doxess is presented in Table 15. The data representation in ecoinvent for each packaging material can be found in Table 11.

Doxess is produced in three thicknesses and the amount of stretch film per 1 kg finished product can differ depending on thickness. Therefore, a conservative assumption is made where the thickness with most stretch film packaging per kg is used.

Table 15 Packaging materials used for the finished products Doxess.

Packaging material	Kg/kg Doxess
Bobbin 76,5*10*515mm	0.192
HD bottenark	0.000178
HD toppark	0.000178
EURO pallet	0.0600
Stretch film (DX, 50% biobased)	0.000432

4 Life cycle impact assessment (LCIA)

4.1 Method for impact assessment

The method chosen for assessing the life cycle impact is called the **CML method.**

The **CML method** was chosen for this study because it is the most recently updated, the most comprehensive and the best adapted to all the environmental effects that are included in this study.

It is a well-recognised scientific method.

Some terms are used below that require clarification:

- Environmental aspect: An activity that might contribute to an environmental effect, for example "electricity usage".
- Environmental effect: An effect that might influence the environment negatively (Environmental impact), for example, "Acidification", "Eutrophication" or "Climate change".
- Environmental impact: The generated damage on a value we want to protect, for example damage on human health, biological diversity etc.

A simple example which incorporates all of the above could be a scenario, where a person drives 1km in a car. This scenario is a direct depiction of an environmental aspect with several different environmental impacts.

> An environmental aspect can be carbon dioxide emission. This can contribute to the environmental effect Global warming which might lead to the environmental impact of flooding, draught and landslide.
> Another environmental aspect could be the consumption of oil that contributes to the environmental effect of resource depletion.

4.1.1 Classification and characterization

Determining what an environmental aspect may contribute to is called *classification*, i.e. use of water contributes to water depletion. How much an aspect contributes to it is called *characterisation*, i.e. usage of 1 ton river water contributes by the factor 1 to water depletion.
Adjusting to how critical that is in a specific area depends on the current environmental load, pressure from resource consumption and the eco system´s carrying capacity. This is done through *normalisation*.

4.2 Impact categories

CML divides the whole environmental impact of the life cycle in 11 different impact categories. All these different categories represent different environmental aspects. Every aspect is then assigned points that represent how serious the environmental aspect is, the higher the score the more serious the environmental aspect. The different categories with the connecting impact category unit can be seen in Table 16.

Table 16 impact category name and unit in CML.

Impact category name	*Unit*
Resource use, mineral and metals	kg Sb eq
Resource use, energy carriers	MJ
Climate change	kg CO2 eq
Ozone layer depletion	kg CFC11 eq
Human toxicity	kg 1,4-DB eq
Freshwater aquatic ecotoxicity	kg 1,4-DB eq
Marine aquatic ecotoxicity	kg 1,4-DB eq
Terrestrial ecotoxicity	kg 1,4-DB eq
Photochemical oxidation	kg C2H4 eq
Acidification	kg SO2 eq
Eutrophication	kg PO4 eq

Resource use: Abiotic depletion factor, ADP, for energy carriers, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed.

ADP for mineral and metal resources, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed.

Impact indicator: Abiotic resource depletion fossil fuels (ADP-fossil); based on lower heating value
Impact indicator: Abiotic resource depletion (ADP ultimate reserve)

Climate change: Climate change causes a number of environmental mechanisms that affect both the endpoint human health and ecosystem health. Climate change models are in general developed to assess the future environmental impact of different policy scenarios. The CML method uses the characterization model as developed by the Intergovernmental Panel on Climate Change (IPCC) for development of characterization factors. Factors are expressed as Global Warming potential for time horizon 100 years (GWP100), in kg carbon dioxide equivalents/kg emission.

Impact indicator: Global Warming Potential 100 years

Ozone layer: The characterisation factor for ozone layer depletion accounts for the destruction of the stratospheric ozone layer by anthropogenic emissions of ozone depleting substances (ODS). These are recalcitrant chemicals that contain chlorine or bromine atoms. Because of their long atmospheric lifetime, they are the source of chlorine and bromine reaching the stratosphere. Chlorine atoms in chlorofluorocarbons (CFC) and bromine atoms in halons are effective in degrading ozone due to heterogeneous catalysis, which leads to a slow depletion of stratospheric ozone around the globe.

Impact indicator: Ozone Depletion Potential (ODP) calculating the destructive effects on the stratospheric ozone layer over a time horizon of 100 years.

Human toxicity (HTP inf), Freshwater aquatic ecotoxicity (FAETP inf), Marine aquatic ecotoxicity (MAETP inf) and Terrestrial ecotoxicity (TETP inf): Characterization factors, expressed as Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP's are expressed as 1,4-dichlorobenzene equivalents/kg emission.

Photochemical ozone formation:
The model is developed by Jenkin & Hayman and Derwent and defines photochemical oxidation expressed in kg ethylene equivalents per kg emission.

Impact indicator: Photochemical ozone creation potential (POCP): Expression of the potential contribution to photochemical ozone formation.
Impact indicator: Photochemical ozone creation potential (POCP): Expression of the potential contribution to photochemical ozone formation.

Acidification: Atmospheric deposition of inorganic substances, such as sulphates, nitrates, and phosphates, cause a change in acidity in the soil. For almost all plant species there is a clearly defined optimum of acidity. A serious deviation from this optimum is harmful for that specific kind of species and is referred to as acidification. As a result, changes in levels of acidity will cause shifts in species occurrence (Goldcorp and Spriensma, 1999, Hayashi et al. 2004). Major acidifying emissions are NOx, NH3, and SO2

Impact indicator: Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area in terrestrial and main freshwater ecosystems, to which acidifying substances deposit.

Eutrophication: Aquatic eutrophication can be defined as nutrient enrichment of the aquatic environment. Eutrophication in inland waters as a result of human activities is one of the major factors that determine its ecological quality. On the European continent it generally ranks higher in severity of water pollution than the emission of toxic substances. Aquatic eutrophication can be caused by emissions to air, water and soil. In practice the relevant substances include phosphorus and nitrogen compounds emitted to water and soil as well as ammonia (NH3) and nitrogen oxide (NOx) emitted to air.

Impact indicator freshwater: Phosphorus equivalents: Expression of the degree to which the emitted nutrients reaches the freshwater end compartment (phosphorus considered as limiting factor in freshwater).

4.3 Results

In this part the result from the different environmental impact assessment methods will be presented.

For each product, DX and Doxess, the results from the CML method for all impact categories will be presented first followed by results in more detail for the impact category climate change.

Due to confidentiality regarding the recipes at Doxa, images in the results have been edited in this version of the LCA report.

4.3.1 DX

Firstly, the results from the CML method for all impact categories will be presented first followed by results in more detail for the impact category climate change.

4.3.1.1 All impact categories

The results from the CML method for all impact categories are presented for 1kg of DX in the table below.

Table 17 Result from impact assessment method CML for DX.

Impact category	Unit	DX 0% biobased	DX 50% biobased	DX 100% biobased
Abiotic depletion	kg Sb eq	1.51E-05	1.49E-05	1.46E-05
Abiotic depletion (fossil fuels)	MJ	81.0	65.1	49.1
Global warming (GWP100a)	kg CO2 eq	2.19	2.29	2.39
Ozone layer depletion (ODP)	kg CFC-11 eq	4.82E-07	3.75E-07	2.68E-07
Human toxicity	kg 1,4-DB eq	0.651	0.550	0.450
Fresh water aquatic ecotox.	kg 1,4-DB eq	0.334	0.285	0.236
Marine aquatic ecotoxicity	kg 1,4-DB eq	814	661	508
Terrestrial ecotoxicity	kg 1,4-DB eq	0.00165	0.00165	0.00165
Photochemical oxidation	kg C2H4 eq	0.000462	0.000412	0.000361
Acidification	kg SO2 eq	0.00672	0.00568	0.00463
Eutrophication	kg PO4--- eq	0.00117	0.00107	0.000965

4.3.1.2 Global warming potential (GWP)

The impact from each phase in the life cycle of the DX products, for all versions of DX, in the impact category climate change are presented in Figure 9. Then Sankey diagrams of the product DX 20 in the three versions will be presented.

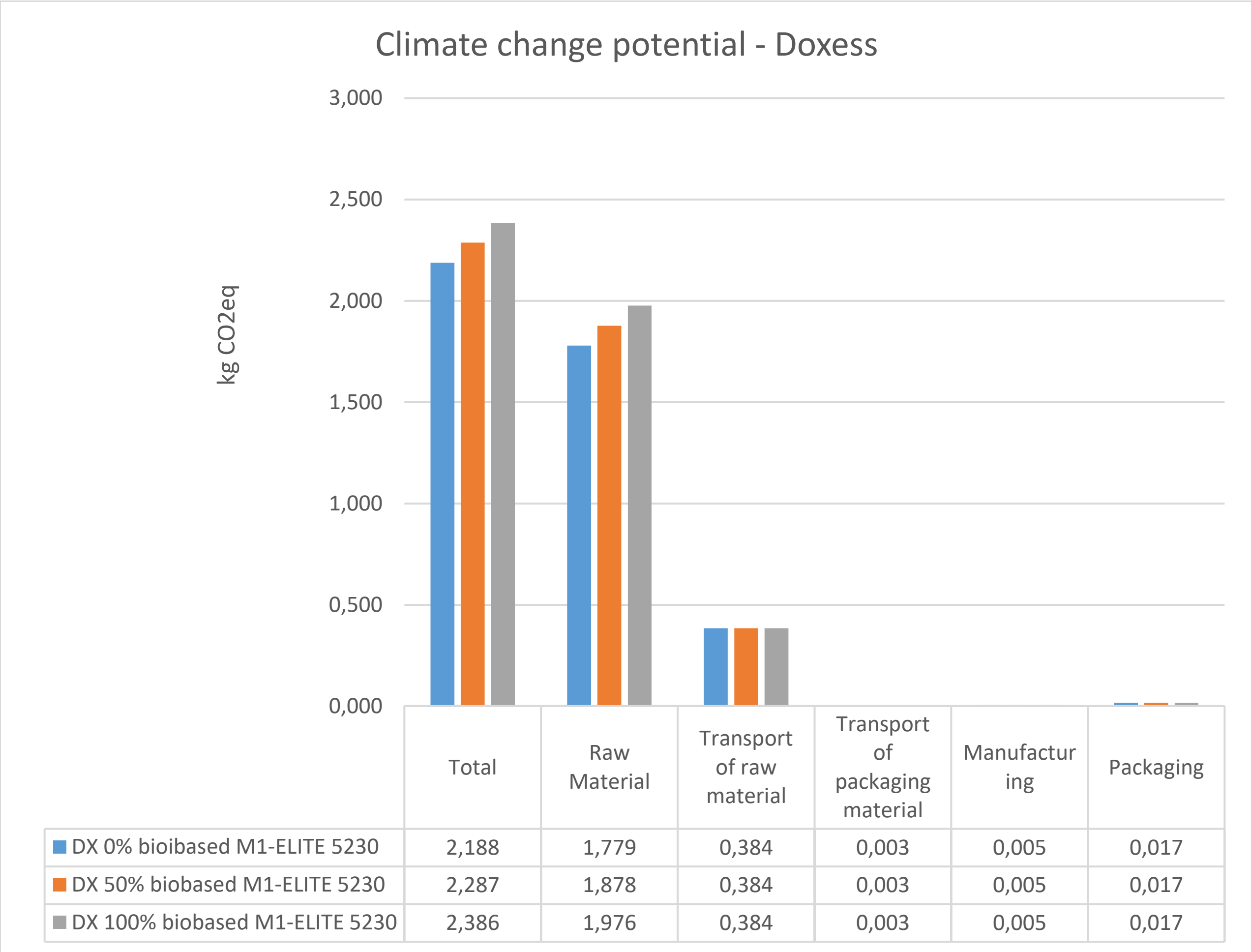


Figure 9 Global warming potential for DX in the three versions 0% biobased, 50% biobased and 100% biobased M1-ELITE 5230.

4.3.1.3 Sankey diagrams DX – climate change potential

Sankey diagrams for the product DX in the three versions are presented in Figure 16 to 18 below. The impact from the different versions of DX, with different amounts of biobased raw material, is illustrated with flows. The flows in the Sankey diagrams for DX illustrate the distribution of the impact from different processes.

DX with 0% biobased M1-ELITE 5230

A Sankey diagram shows the flow with the thickness of the arrows. The cut-off of the Sankey Diagram is set to 5% which means that only processes that contribute to more than 5% of the total climate change potential are included in the diagram. Seen to the total 11 of 12876 contributing processes are shown in the Sankey diagram.

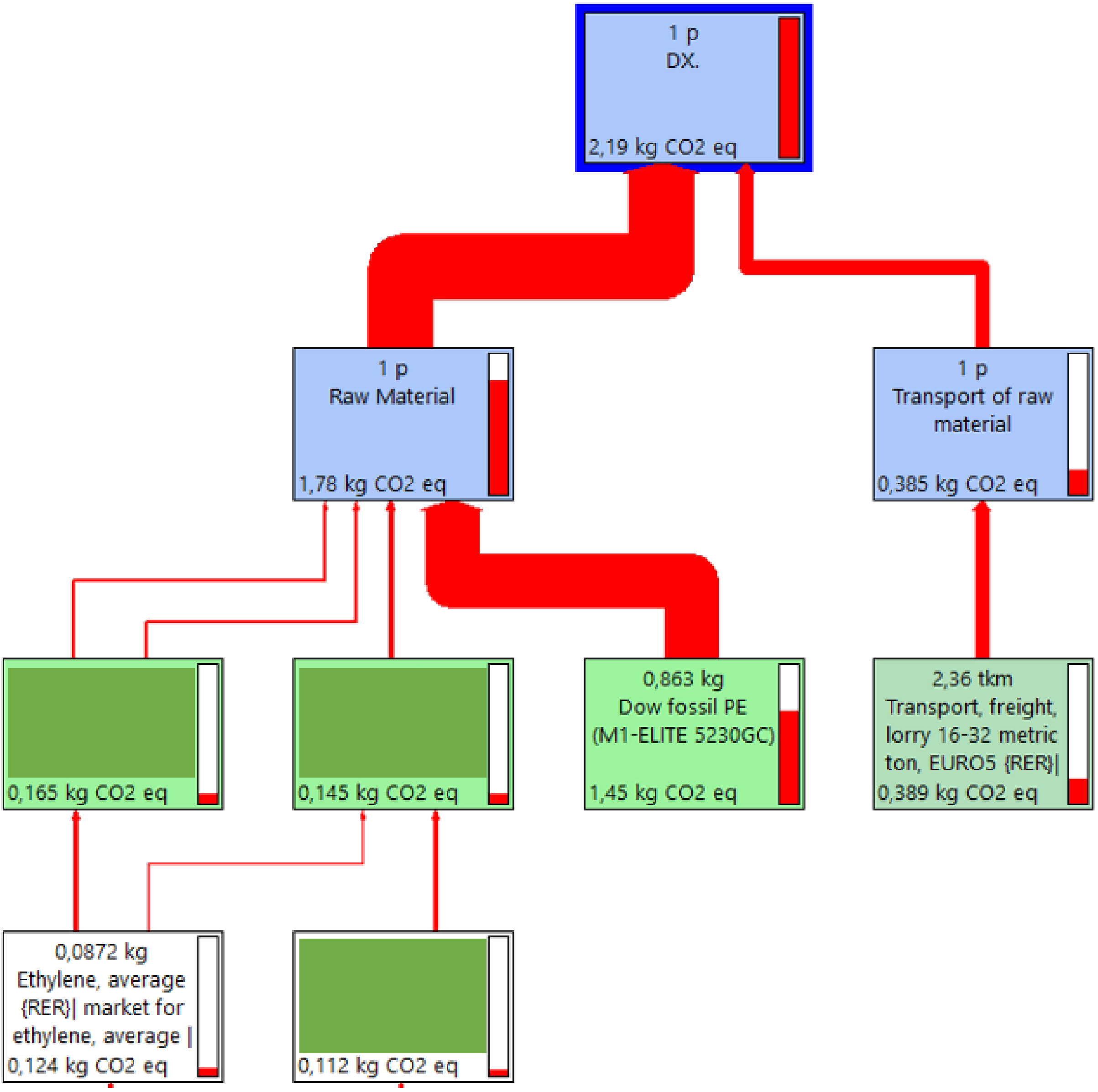


Figure 10 Sankey diagram for DX 20 micron with 0% biobased M1-ELITE 5230.

DX with 50% biobased M1-ELITE 5230

A Sankey diagram shows the flow with the thickness of the arrows. The cut-off of the Sankey Diagram is set to 5% which means that only processes that contribute to more than 5% of the total climate change potential are included in the diagram. Seen to the total 10 of 12877 contributing processes are shown in the Sankey diagram.

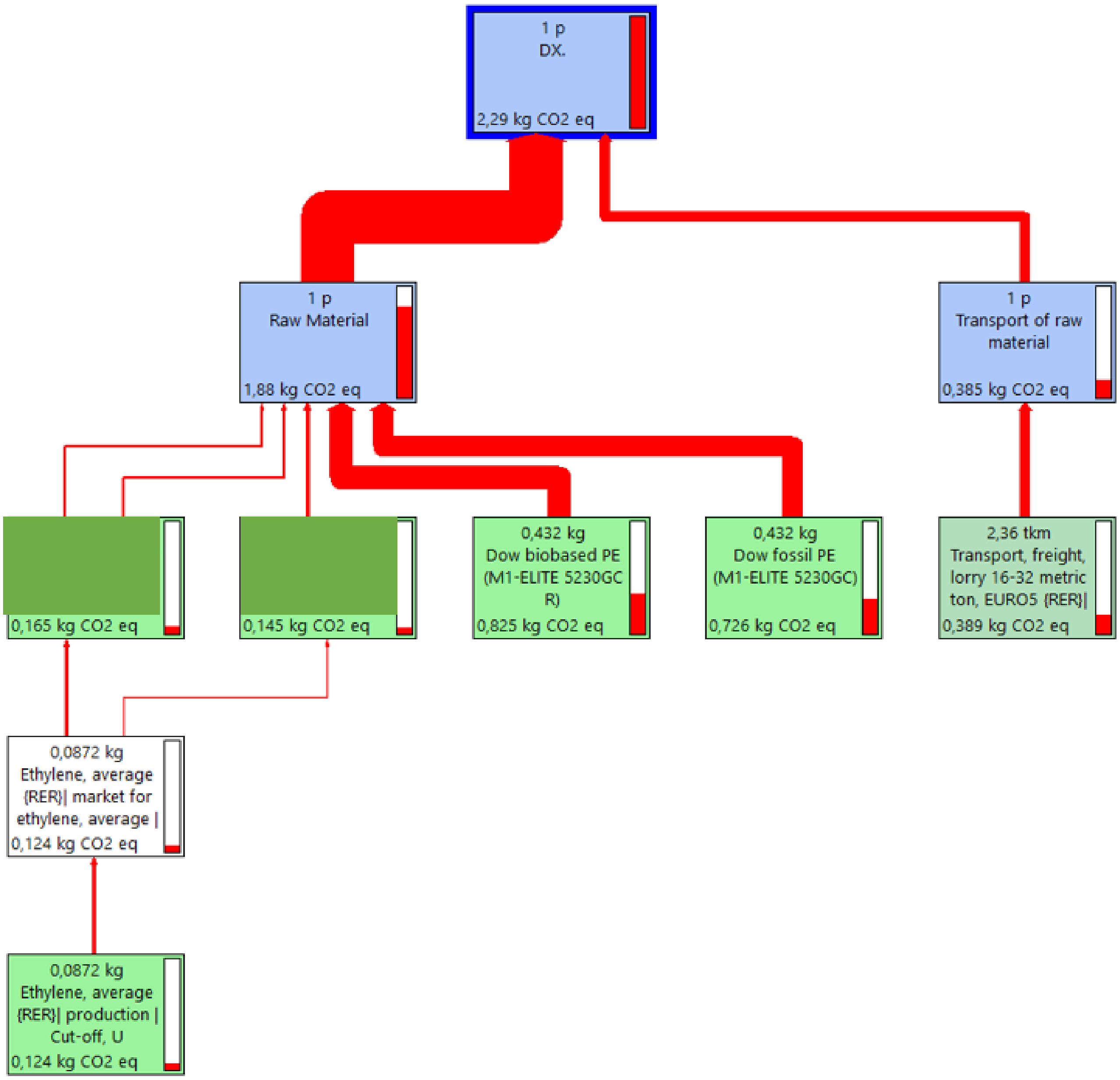


Figure 11 Sankey diagram for DX 20 micron with 50% biobased M1-ELITE 5230.

DX with 100% biobased M1-ELITE 5230

A Sankey for DX with 100% biobased M1-ELITE 5230. The cut-off of the Sankey Diagram is set to 5% which means that only processes that contribute to more than 5% of the total climate change potential are included in the diagram. Seen to the total 9 of 12876 contributing processes are shown in the Sankey diagram.

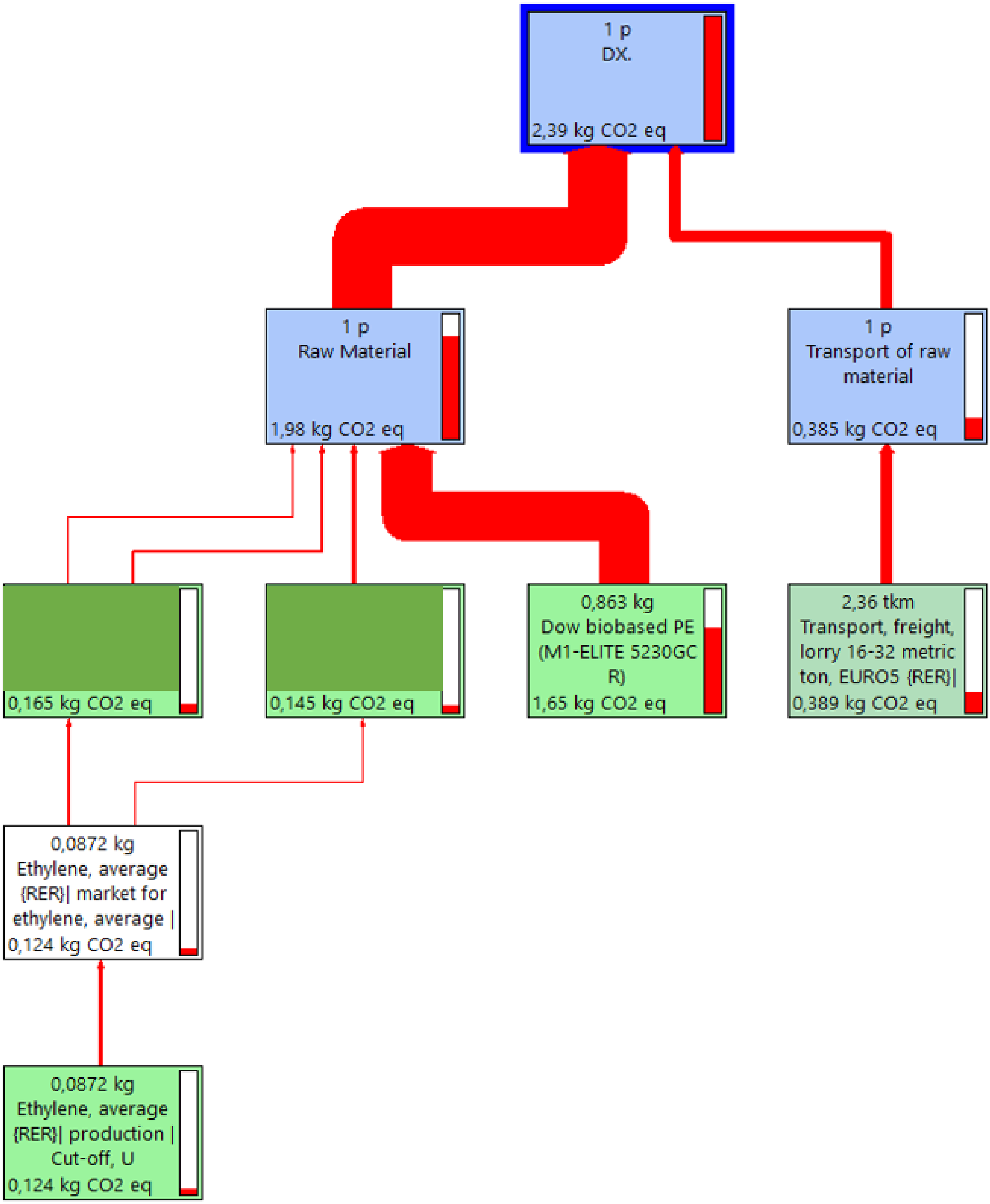


Figure 12 Sankey diagram for DX 20 micron with 100% biobased M1-ELITE 5230.

4.3.2 Doxess

The results from the CML method will be presented first for all impact categories and then for global warming potential (GWP).

4.3.2.1 All impact categories

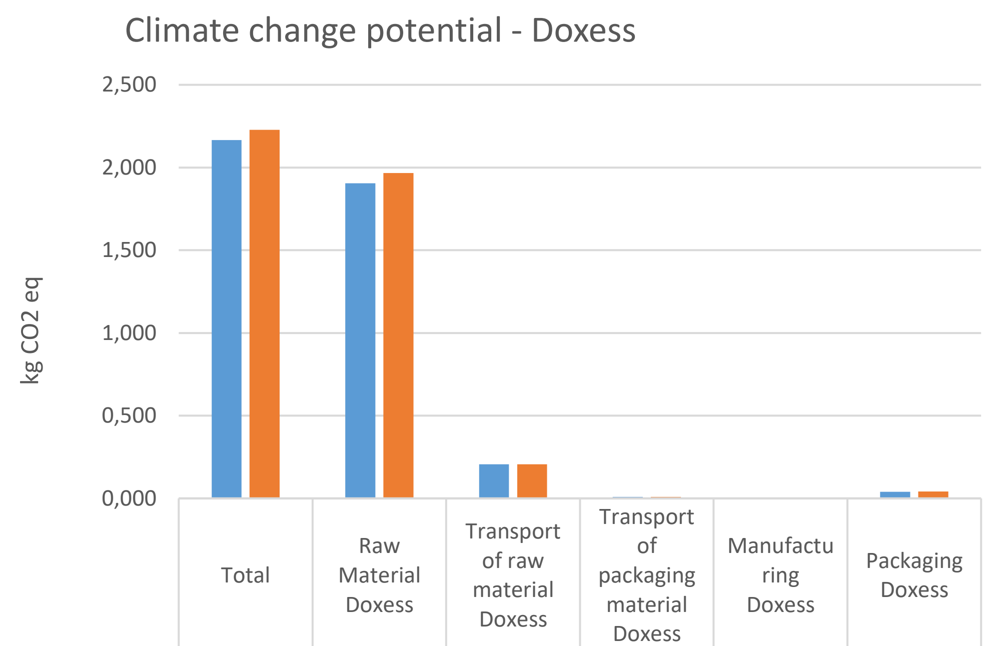
The results from the CML method for all impact categories are presented for each thickness in the tables below.

Table 18 Result from impact assessment method CML for Doxess.

Impact category	Unit	Doxess 0% biobased	Doxess 100% biobased
Abiotic depletion	kg Sb eq	2.09E-05	2.07E-05
Abiotic depletion (fossil fuels)	MJ	73.7	63.5
Global warming (GWP100a)	kg CO2 eq	2.17	2.23
Ozone layer depletion (ODP)	kg CFC-11 eq	2.16E-07	1.47E-07
Human toxicity	kg 1,4-DB eq	1.06	0.999
Fresh water aquatic ecotox.	kg 1,4-DB eq	0.599	0.568
Marine aquatic ecotoxicity	kg 1,4-DB eq	1198	1101
Terrestrial ecotoxicity	kg 1,4-DB eq	0.00183	0.00183
Photochemical oxidation	kg C2H4 eq	0.000568	0.000536
Acidification	kg SO2 eq	0.00832	0.00765
Eutrophication	kg PO4--- eq	0.00169	0.00163

4.3.2.2 Global warming potential - CML

The results for all thicknesses and versions of Doxess in the impact category climate change is shown in Figure 13. The figure shows the impact from each phase in the life cycle of the Doxess products.



	Total	Raw Material Doxess	Transport of raw material Doxess	Transport of packaging material Doxess	Manufacturing Doxess	Packaging Doxess
Doxess 0% biobased M1-ELITE 5230	2,166	1,904	0,206	0,009	0,005	0,041
Doxess 100% biobased M1-ELITE+Doxess!$30:$30 5230	2,229	1,967	0,206	0,009	0,005	0,041

Figure 13 Global warming potential in all life cycle phases for the Doxess products.

4.3.2.3 Sankey diagrams Doxess – climate change potential

Sankey diagrams for the product Doxess in the three versions are presented in Figure 14 and Figure 15.

Doxess with 0% biobased M1-ELITE 5230

A Sankey for Doxess with 0% biobased M1-ELITE 5230. The cut-off of the Sankey Diagram is set to 5% which means that only processes that contribute to more than 5% of the total climate change potential are included in the diagram. Seen to the total 12 of 12882 contributing processes are shown in the Sankey diagram.

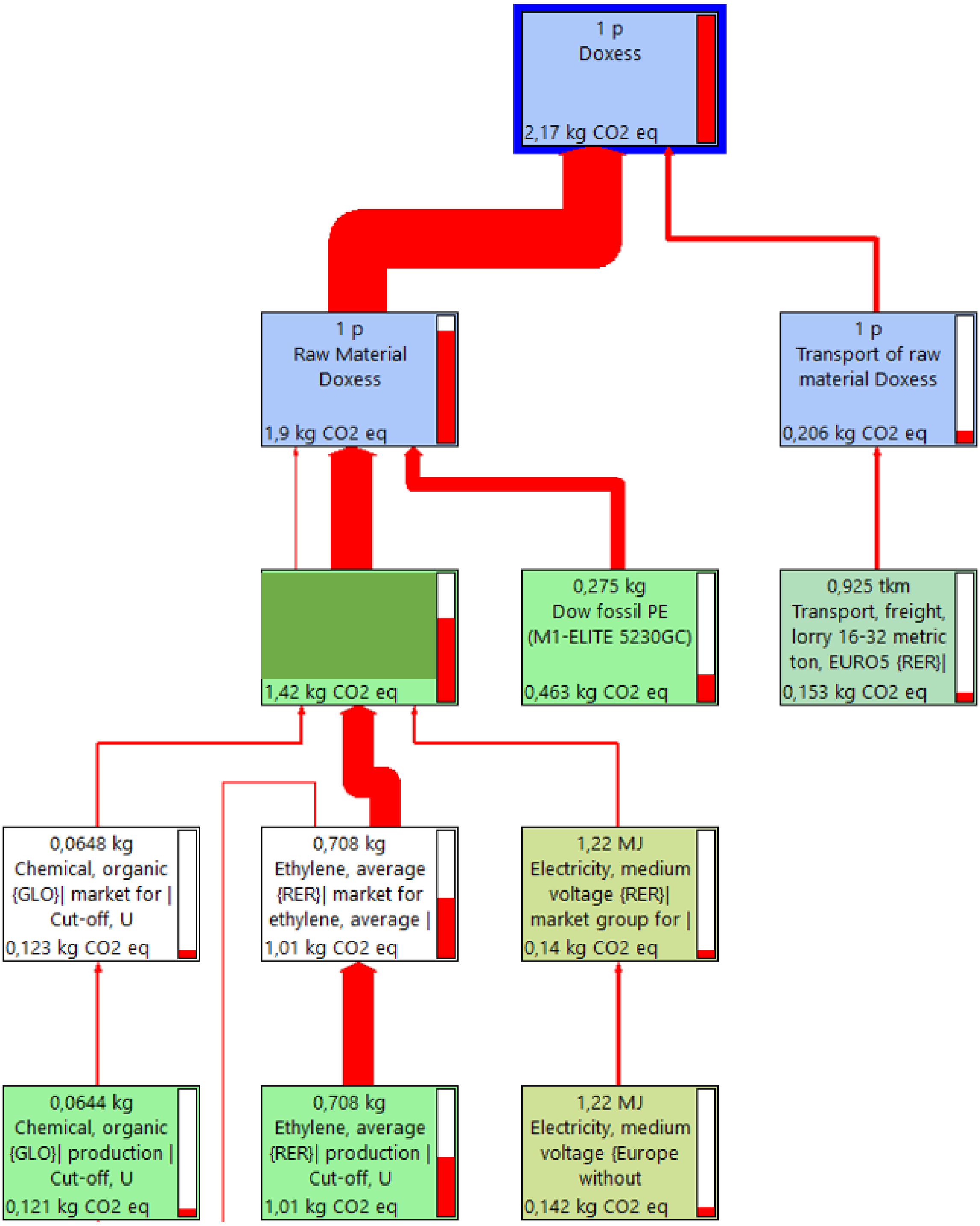


Figure 14 Sankey diagram for Doxess 5 micron with 0% biobased M1-ELITE 5230.

Doxess with 100% biobased M1-ELITE 5230

A Sankey for Doxess with 100% biobased M1-ELITE 5230. The cut-off of the Sankey Diagram is set to 2% which means that only processes that contribute to more than 2% of the total climate change potential are included in the diagram. Seen to the total 14 of 12882 contributing processes are shown in the Sankey diagram.

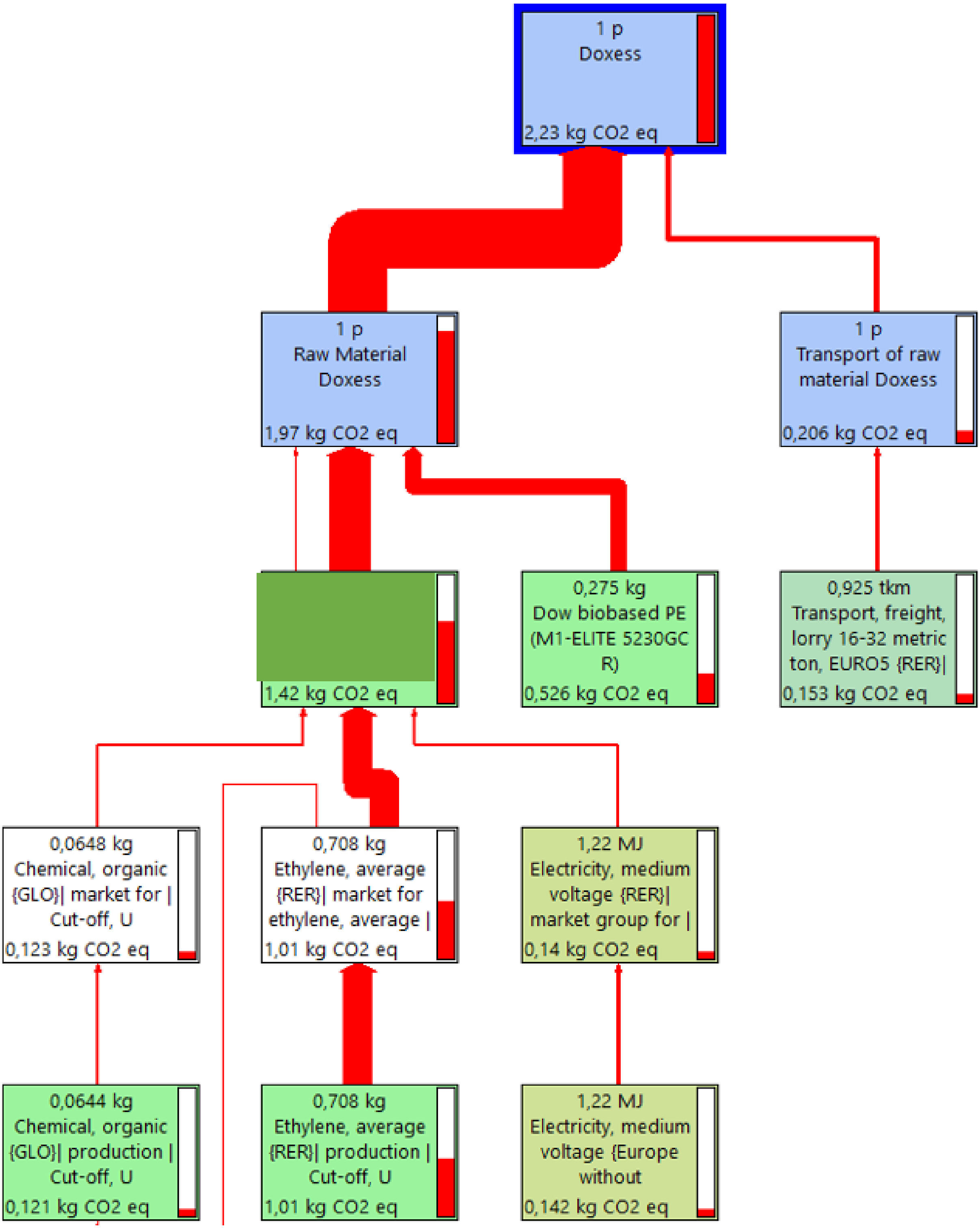


Figure 15 Sankey diagram for Doxess 5 micron with 100% biobased M1-ELITE 5230.

5 Interpretation

5.1 Completeness check

The objective of the completeness check is to ensure that all relevant information and data needed for the interpretation are available and complete. If any relevant information is missing or incomplete, the necessity of such information for satisfying the goal and scope of the LCA shall be considered. This finding and its justification shall be recorded.

In reference to the goal and scope of the report the report is complete.

5.2 Sensitivity analysis

5.2.1 Electricity in manufacturing at Doxa

Doxa uses electricity from 100% renewable energy by hydro power in Sweden, certificate according to GoO (Guarantee of Origin) can be seen in Appendix 4. A sensitivity check is made to assess the impact of using renewable electricity as opposed to electricity from the Swedish national grid in the manufacturing. The impact on climate change potential 1 kWh of electricity calculated with IPCC 100a can be seen in the tabled below.

Table 19 Climate change potential of 1 kWh electricity, calculated with IPCC GWP 100a.

	Unit	Renewable energy from hydropower (1kWh)	Swedish national grid (1kWh)
Climate change potential (IPCC GWP 100a)	kg CO2eq	0.00395	0.0491

Th impact from the manufacturing per kg of material increases from 0.005 kg CO2eq to 0.04 kg CO2eq, which is an increase of 800%. Using Swedish electricity from the national grid in the manufacturing of DX 100% biobased M1-ELITE 5230 increases the total climate change potential to 2.42 kg CO2 from 2.39 kg CO2eq which corresponds to an increase of 1%. For DX 0% biobased M1-ELITE 5230, the results increase to 2.22 kg CO2eq corresponding to an increase of the climate change potential 2%.

5.2.2 Packaging

As stated in 3.2.6, the amount of stretch film packaging per kg finished Doxess can differ depending on the thickness. Therefore, a conservative assumption is made where the thickness with most stretch film packaging is used. Reducing the plastic packaging with 30% to 39% would not have a significant impact on the results on climate change potential for Doxess since the total impact from all packaging is 2 %

5.2.3 End-of-life

The end-of-life phase was not included in the system boundary. To evaluate the impact of the exclusion of the end-of-life phase an end-of-life scenario is calculated based on Swedish general data for recycling of plastic packagings. According to SCB (2020a) 49% of plastic packagings are recycled. Plastic packagings that are not recycled are incinerated (SCB, 2020b).

Table 20 Waste treatment scenarios for plastic.

Waste treatment	Share of waste flow	Description of LCI data in ecoinvent	Source
Recycling	49%	PE (waste treatment) {GLO}| recycling of PE | Cut-off, U	SCB, 2020a
Incineration	51%	Waste polyethylene {CH}| treatment of, municipal incineration with fly ash extraction | Cut-off, U	SCB, 2020b

For DX, the end-of-life scenario generates an increase climate change potential corresponding to 18%-70% depending on amount of biobased raw material, see the table below. For Doxess the increase of climate change potential is 53%-71%. This means that it is important for Doxa to make sure that the plastic products are recycled and work with closing the loop for the material flow. The impact on climate change potential from a general waste treatment scenario is 1.54 kg CO2 eq for DX 0% biobased M1-ELITE 5230, see figure below.

Table 21 Climate change potential for the end-of-life scenario of the different products, CML method.

Product	Climate change potential	Increase in GWP
DX 0% biobased M1-ELITE 5230	1.54 kg CO2eq	70%
DX 50% biobased M1-ELITE 5230	0.987 kg CO2eq	43%
DX 100% biobased M1-ELITE 5230	0.434 kg CO2eq	18%
Doxess 0% biobased M1-ELITE 5230	1.51 kg CO2eq	71%
Doxess 100% biobased M1-ELITE 5230	1.19 kg CO2eq	53%

5.3 Discussion, limitations and conclusions

The discussion will focus mainly on the impact category climate change since Doxa are especially interested in gaining an understanding of the impact from the products on the impact category climate change.

5.3.1 DX – climate change

Most impact on climate change potential, 82%-83%, occur in the raw material phase. The Sankey diagrams, Figure 10 to Figure 12, for DX illustrate that most of the impact comes from the M1-ELITE 5230 raw materials, both the biobased and the fossil version. The biobased M1-ELITE 5230 contributes with a larger impact on climate change potential than the fossil M1-ELITE 5230. Due to the aggregated data provided by Dow, it is not possible to determine which processes in the raw material that generates most impact. It is of interest for Doxa to investigate this in collaboration with Dow and see which improvements that can be done in the raw material to reduce the impact.

5.3.2 Doxess - climate change

Most impact on climate change potential, 88%, occur in the raw material phase, where most part is generated by the LLDPE. It is the ethylene used to produce the LLDPE that is the hotspot in the LLDPE.

Since general data is used to model the LLDPE, it is of interest for Doxa to dig deeper into the LLDPE and get specific data to find opportunities to reduce the environmental burden from the Doxess products.

5.3.3 Thicknesses

Both DX and Doxess comes in different thicknesses. Seen in the tables below is the climate change potential for each thickness. When investigating the impact per thickness it is also important to take into consideration the possibility to stretch the specific thickness. For example, DX10 microns can be stretched so that 1m2 of product covers 2m2, resulting in a GWP of 0.01kg CO2eq for the 0% biobased version. For DX 23 microns, it is possible to stretch 1 m2 to cover 4m2, resulting in a GWP of 0.012 kg CO2eq.

Table 22 GWP (kgCO2eq) per m2 for the different thicknesses of DX.

Thickness	Weight [kg/m2]	GWP/m2 for DX 0% biobased	GWP/m2 for DX 50% biobased	GWP/m2 for DX 100% biobased
10 micron	0.0092	0.0201	0.0210	0.0219
12 micron	0.011	0.0241	0.0252	0.0262
15 micron	0.0138	0.0302	0.0316	0.0329
17 micron	0.0156	0.0342	0.0357	0.0372
20 micron	0.0183	0.0400	0.0419	0.0437
23 micron	0.0211	0.0462	0.0483	0.0503

Table 23 GWP (kg CO2eq) per m2 for all thicknesses of Doxess.

Thickness	Weight [kg/m2]	GWP/m2 for Doxess 0% biobased	GWP/m2 for Doxess 100% biobased
5 micron	0.0046	0.00997	0.0103
6 micron	0.0055	0.0119	0.0123
7 micron	0.0064	0.0139	0.0143

5.3.4 End-of-life

As seen in the sensitivity check, adding and end-of-life scenario can increase the impact on climate change potential with 71% for the fossil product. Using biobased raw material in the products leads to a lower impact on climate change potential from the end-of-life scenario phase compared to the fossil product. As seen in the sensitivity check, the impact of the end-of-life phase is 18% for the DX product with 100% biobased M1-ELITE 5230. Although, the end-of-life is not included in the cradle to gate perspective it is important to consider what the end-of-life scenario is for the product[5]. To reduce the impact from the end-of-life phase Doxa con work on making sure that the plastic products are recycled and work with closing the loop for the material flow, for example by engaging in initiatives for closing the loop on plastic materials such as take-back systems.

[5] The 100% biobased M1-ELITE 5230 is regarded as biogenic carbon in incineration at the end of life, when it is burned and emitted to the air it has zero global warming potential since the emissions are equal to the uptake in the growth phase. If the biobased raw material is used in an application where it will be stable for 100 years, then it should be considered as a sequestering of CO2 from the atmosphere to the earth.

5.3.5 Comparison to general data

The data provided by Dow is aggregated and hence it is not possible to determine which processes that contribute most to the total impact for the raw materials supplied by Dow. To evaluate the results provided, the impact on climate change for the raw materials from Dow are compared to generic data, representing Europe from ecoinvent and a case from a previous study conducted by Miljögiraff (Wendin, 2020).

The results on climate change for the raw materials from Dow correspond to 1.91 kg CO2 eq for the biobased M1-ELITE 5230 and 1.68 kg CO2 eq for the fossil M1-ELITE 5230. General data in ecoinvent for linear low-density polyethylene, LLDPE, corresponds to 1.88 kg CO2 eq and for low density polyethylene, LDPE, the result for climate change is 1.95 kg CO2 eq. The fossil raw material from Dow has 11% lower impact than the generic LLDPE and 14% lower impact than the generic LDPE. The biobased raw material from Dow has 2% more impact on climate change compared to the generic LLDPE and 2% less impact on climate change potential than the generic LDPE.

Generic data for recycled HDPE generates an impact of 0.663 kg CO2eq. Compared to the biobased M1-ELITE 5230, the impact on climate change potential for the recycled HDPE is 65% lower. It is therefore of interest for Doxa to investigate possibilities to use recycled raw material in the products to reduce the impact.

5.3.6 Uncertainty of data

Due to confidentiality, Dow did not want to share information regarding their processes for producing the raw material. The data received from Dow was from an internal LCA made by Helling (2020), which had not been third party verified. This source of data is therefore uncertain from an LCA perspective since there is no way to validate the correctness of the data. The issues with using this type of data were discussed with Doxa before deciding to use it.

5.3.7 Land use

When assessing the impact from a biobased plastic product it is preferred to include the impact category land use in the assessment. The biobased raw material originates from trees, and the forestry in turn has an impact on land use. The impact category land use is not included in the CML method. It is of interest to investigate the possibility to include this impact category in future assessments.

5.3.8 Further investigations

Due to the aggregated data from Dow, it is not possible to determine which processes in the manufacturing of the M1-ELITE 5230 PE that generate most impact in the different categories. Therefore, it is of interest to continue to dig deeper into the data for these raw materials. Especially, it would be interesting to find out why the biobased raw material generate more impact on climate change potential than the fossil raw material.

It would also be interesting for Doxa to investigate the possibility to use recycled materials in their products.

5.3.9 Conclusions and recommendations

- Investigate the possibilities to reduce the impact from the raw material provided from Dow. In further investigations it is of interest to get more specific, unaggregated data from Dow for transparency.
- Investigate the possibility to reduce the impact on climate change potential for the LLDPE used in the Doxess products in collaboration with suppliers.
- Investigate the possibility to use recycled raw materials in the products.
- The end-of-life phase is important from a life cycle perspective and can generate a 71% increase of GWP/kg for the fossil product. Using biobased raw materials in the products generates significantly less impact in the end-of-life phase compared to the fossil product, and this is the main benefit of using biobased raw materials.
- To reduce the impact from the end-of-life phase, Doxa can engage in initiatives for closing the loop on plastic materials such as take-back systems for example.

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7 Appendix

Appendix 1, Methods for Impact Assessment

Classification

Classification means that all categories of data are sorted into different categories of environmental effects. Readymade methods for this have been used in order to evaluate a broader perspective and find the most potential categories. The mostly used methods being Ecoindicator and EPS. These methods include also characterisation (and weighting described further).

The aim with the characterisation is to quantify each element's contribution to the different categories of environmental effect, respectively. To do this, each category of environmental effect is multiplied with characteristic factors which are specific for the data- and the category of environmental effect. The result from the characterisations gives answer about what or which emissions that leads to a significant environmental influence. For each characteristic factor calculates the potential environmental influence which could arise if an element released to the environmental or if a resource is consumed.

Classification and characterisation are where all items in the inventory are assigned to the effect it is likely to have on the environment.

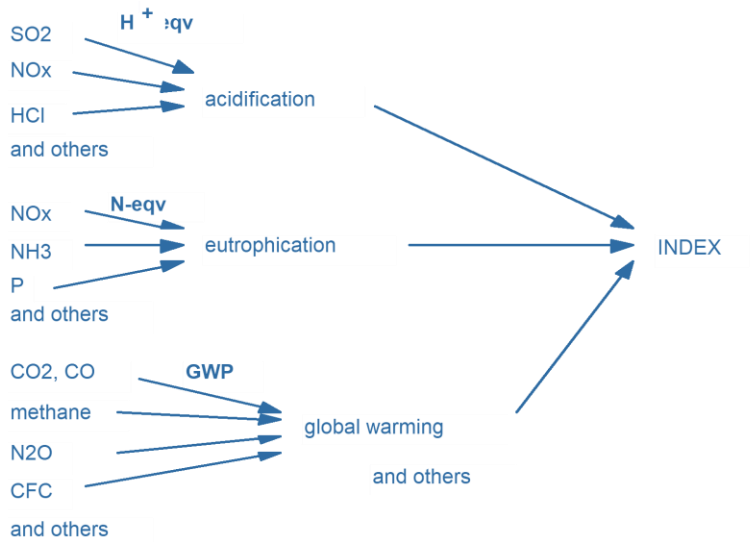


Figure 16: An illustration of the Impact Assessment of an LCA.

When this link is determined, we call it an environmental aspect. This environmental aspect has to be linked between the environment and the process before you can say that it is established and that the process is unsustainable. In the early stages of Lifecycle Assessment substances that were found in the inventory was assigned to environmental aspects. In order to reach for the ultimate goal of sustainability, it is important also to describe the local and global environment. Environmental aspects that may have an impact are located and after that, the link to the inventory and to the process path features may be analysed and established.

Impact assessment method CML
CML LCIA Methodology Life cycle assessment (LCA) is a methodological tool used to quantitatively analyse the life cycle of products/activities. ISO 14040 and 14044 provide a generic framework.

After goal and scope has been determined, data has been collected, an inventory result is calculated. This inventory result is usually a very long list of emissions, consumed resources and sometimes other items. The interpretation of this list is difficult. An LCIA procedure, such as the CML method is designed to help with this interpretation.

The primary objective of the CML method is to transform the long list of inventory results, into a limited number of indicator scores. These indicator scores express the relative severity on an environmental impact category.

A closer description of the different environmental effect categories calculated with CML Method can be seen below:

<u>Climate change:</u> Climate change causes a number of environmental mechanisms that affect both the endpoint human health and ecosystem health. Climate change models are in general developed to assess the future environmental impact of different policy scenarios. The CML method uses the characterization model as developed by the Intergovernmental Panel on Climate Change (IPCC) for development of characterization factors. Factors are expressed as Global Warming potential for time horizon 100 years (GWP100), in kg carbon dioxide equivalents/kg emission.

<u>Ozone layer:</u> The characterisation factor for ozone layer depletion accounts for the destruction of the stratospheric ozone layer by anthropogenic emissions of ozone depleting substances (ODS). These are recalcitrant chemicals that contain chlorine or bromine atoms. Because of their long atmospheric lifetime, they are the source of Chlorine and Bromine reaching the stratosphere. Chlorine atoms in chlorofluorocarbons (CFC) and bromine atoms in halons are effective in degrading ozone due to heterogeneous catalysis, which leads to a slow depletion of stratospheric ozone around the globe.

<u>Acidification (incl. fate, average Europe total, A&B):</u> Atmospheric deposition of inorganic substances, such as sulphates, nitrates, and phosphates, cause a change in acidity in the soil. For almost all plant species there is a clearly defined optimum of acidity. A serious deviation from this optimum is harmful to that specific kind of species and is referred to as acidification. As a result, changes in levels of acidity will cause shifts in species occurrence (Goldcorp and Spriensma, 1999, Hayashi et al. 2004). Major acidifying emissions are NOx, NH3, and SO2

<u>Eutrophication (fate not included):</u> Aquatic eutrophication can be defined as nutrient enrichment of the aquatic environment. Eutrophication in inland waters as a result of human activities is one of the major factors that determine its ecological quality. On the European continent, it generally ranks higher in the severity of water pollution than the emission of toxic substances. Aquatic eutrophication can be caused by emissions to air, water and soil. In practice, the relevant substances include phosphorus and nitrogen compounds emitted to water and soil as well as ammonia (NH3) and nitrogen oxide (NOx) emitted to air.

<u>Toxicity:</u> The characterisation factor of human toxicity and ecotoxicity accounts for the environmental persistence (fate) and accumulation in the human food chain (exposure), and toxicity (effect) of a chemical. Fate and exposure factors can be calculated by means of ‘evaluative’ multimedia fate and

exposure models, while effect factors can be derived from toxicity data on human beings and laboratory animals (Hertwich et al., 1998; Huijbregts et al., 2000).

Fossil depletion: The term fossil fuel refers to a group of resources that contain hydrocarbons. The group ranges from volatile materials (like methane) to liquid petrol, to non-volatile materials (like coal). There is a highly politicised debate on the availability of conventional (liquid) oil, and this makes it difficult to obtain reliable, unbiased data. The spectrum of views ranges from the Peak-oil movement (www.aspo.org or peak-oil.com) to international organisations like the International Energy Agency (IEA), or commercial organisations like the Cambridge Energy Research Agency (CERA). Therefore, it is hard to determine the seriousness of the depletion of oil, and which model to use, for this category, the IEA model is used.

Appendix 2, IPCC 2013

Direct solar radiation heats the Earth. The heated crust emits heat radiation which partially are absorbed by gases, known as greenhouse gases, in the Earth's atmosphere. Some of this heat radiation rays back to Earth and heat the Earth. This natural greenhouse effect is essential for life on Earth. However, because of human activity, the presence of greenhouse gases in the atmosphere, such as carbon dioxide, methane, and nitrous oxide, have increased. This affects the natural radiation balance, which leads to global warming and climate changes.

The potential impact on the climate is calculated using the IPCC 2013 GWP 100 v.1.03 (IPCC, 2013), model Global Warming Potential, GWP. The impact of climate gases is expressed as carbon dioxide equivalents, CO2 eq. It is the most established scientific method. It has been implemented in the CML method.

Appendix 3, ecoinvent

Ecoinvent is one of the world-leading databases with consistent, open, and updated Life Cycle Inventory Data (LCI).

With several thousand LCI data sets in the fields of agriculture, energy supply, transport, biofuels and biomaterials, bulk and speciality chemicals, construction and packaging materials, basic and precious metals, metals, IT and electronics and waste management, ecoinvent offers the most comprehensive international LCI database.

Ecoinvent’s high-quality LCI data sets are based on industrial data and have been compiled by internationally recognised research institutes and LCA consultants.

Appendix 4, certificate according to Guarantee of Origin

Doxa Plast i Värnamo AB

köper förnybar el från urspungsmärkt vattenkraft under avtalstiden. På så sätt stödjer ni effektiviseringen av vattenkraft och minskar företagets miljöpåverkan.

Vi garanterar att er årsförbrukning framställs i form av vattenkraft.

Intyget gäller för okt 2020 och tillsvidare

Bästa hälsningar

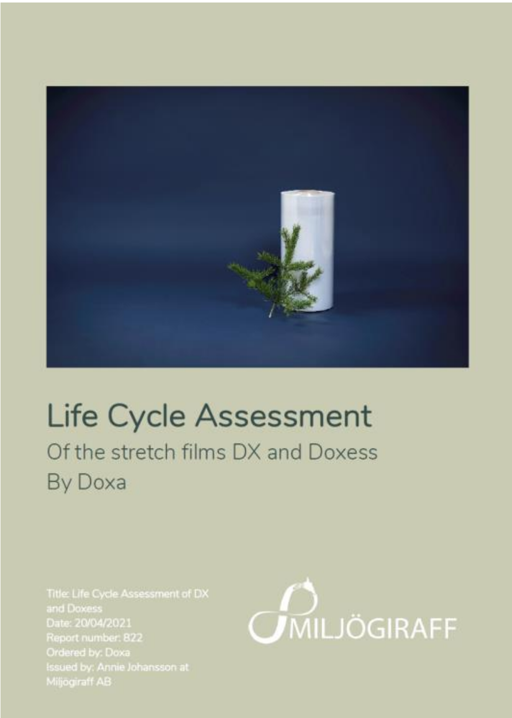
Emma Borgström
Head of Energy Sales B2B
E.ON Energilösningar AB

e·on

REVIEW REPORT

2021-05-28

Reviewed LCA: Life Cycle Assessment of the Stretch films DX and Doxess, by Doxa



REVIEW ORDERED BY:
DOXA PLAST I VÄRNAMO AB

REVIEW PERFORMED BY:
MARTYNA MIKUSINSKA
SWECO AB, ÖREBRO MILJÖ

Summary

This report summarizes the results from the third-party review of the project report *Life Cycle Assessment of the Stretch films DX and Doxess*, performed by Miljögiraff AB (Annie Johansson). The critical review has been performed by Martyna Mikusinska at Sweco, in accordance with the ISO 14040-44 standard series.

The report includes a short presentation of the main features of the reviewed LCA report and summarises questions and comments that have been communicated during the review.

The verifying party hereby certifies that the results of the performed LCA corresponds to the requirements of ISO 14040 and 14044.

Martyna Mikusinska, Sweco, 2021-05-28

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Table of Contents

1 Background, Goal and Scope

Miljögiraff has performed an attributional LCA on the two types of stretch film, Doxa DX and Doxess, produced by Doxa. Doxa commissioned this study with the to understand the environmental impact of Doxa DX and Doxess to find opportunities to mitigate the adverse effects and increase the potential contribution to sustainable development.

The LCA has been performed in accordance with the ISO 14040 standard.

Results of the study will primarily be made available externally to customers and stakeholders.

In this critical review, aspects defined in the ISO-standard for LCA (ISO 14040:2006 *Environmental management - Life cycle assessment - Principles and framework* and ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines) are evaluated. The review considers the four main steps in the LCA; goal and scope definition, inventory analysis, presentation and evaluation of environmental impacts, and interpretation.

1.1 Description of the Reviewed LCA

In the table below, basic information concerning performed LCA is presented.

Title	*Life Cycle Assessment of the Stretch films DX and Doxess*
Commissioner of LCA	*Doxa*
Author and performer of LCA	Miljögiraff AB (Annie Johansson)
Dialogue with verifier performed during the execution of the study?	*Yes, between review round 1 and 2. Substantial changes in project report were made.*
Assessed product	*Stretch film for machine or manual use, with different amounts of biobased content.*
Declared unit	*1 kg of product*
Scope	*Cradle to gate*
Performed according to standard	*ISO/TS 14040 and 14044*
Comparative assessment	*No*
Results disclosed in public	*Yes*
Reviewed documentation	*LCA-report, 41 pages excluding appendices and 2 appendices.*
Software for assessment of background data	*SimaPro 9*
Background database	*Ecoinvent 3.6*

Specific data	*Manufacturing stage, including all data concerning material, energy, and waste.*
Provision of LCI-data for review	*Documentation in report including of all the main material- and energy flows, and screen dumps from the SimaPro-model.*
LCIA method	CML-IA Baseline v. 4.7
Date for submission of LCA-report for review	*2021-04-20*
Phases during the verification process	*Review of LCA-report in two steps and feedback after each review.*
Verifier	*Martyna Mikusinska, Sweco*

2 Standards and Criteria for Review

The critical review has been performed in accordance with guidelines in the ISO 14040 and ISO 14044 standards. Focus of the review has been on the following five aspects:

- the methods used to carry out the LCA are consistent with the standard,
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

2.1 Performed Review

The review is based on the four main steps of LCA as stated in the ISO-standard; goal and scope definition, inventory analysis, impact assessment and interpretation.

Concerning the first step, definition of goal and scope, the functional/declared unit, definition of system boundary, allocation procedures, assumptions and choice of method and impact categories for the LCIA are reviewed.

The inventory analysis has been reviewed focusing on collected specific data, process tree, calculations and choice of generic data. The clarity and transparency of these aspects was considered.

Concerning the LCIA, the focus of the review has been on the consistency between inventoried data and results as well as the presentation of results. No sampling of results has been performed.

The evaluation of the interpretation step was based on performed sensitivity analyses, the validity of results, discussion of results in relation to earlier studies, and recommendations.

Grammar and spelling has not been taken into account.

2.2 Review Procedure

The procedure for the external review has been done as follows:

A first review of the final draft of the LCA-report was conducted in January 2021. During this review, *Review dialogue ver.1* was written to communicate review comments and question.

This review dialogue was sent to the commissioner and authors of the report for addressing of comments and revision of report.

After this review round, the commissioner and practitioner of the LCA-report decided to do several changes in the report, for instance, the declared unit was changed from 1 m^2 to 1 kg of product. Changes were also made in the inventory and results of the report.

Revised report and responded comments from Review dialogue ver.1 were sent to reviewer by the end om April, and the next review round was conducted in May. During the second review round, a few minor questions were resolved, and the report was accepted by the reviewer.

All of the communication throughout the review is documented in section 3 of this review report.

The review report should be attached to the final version of the LCA-report to ensure transparency.

3 Documentation of communication during review

In the table below, review comments are summarized in the chronological order of goal and scope definition, inventory analysis, impact assessment and interpretation.

No.	Section	Review comment	Answer	Acceptance of revision
1	Report in general	Report is structured according to the four phases of ISO 14040, and has a clear disposition.	-	
2	Goal, scope, and method	The functional unit of the product is described as 1 m2 of material. Is there any relevant measure of performance concerning reviewed products	The functional unit has now been changed to a	ok

No.	Section	Review comment	Answer	Acceptance of revision
		(toughness/elasticity/durability)? Are they equal in comparison?	declared unit of 1kg of material.	
3	Goal, scope and method	Why has end of life been excluded? The environmental impacts from end of life have been calculated and described in report and I do not see why the scope shouldn't include end of life, as it would greatly affect the results of the comparison and is a most relevant part of the LC.	An explanation has been added in section 2.3.2 on page 11.	Ok, motivation accepted. Good that end of life is included in sensitivity analysis.
4	Goal, scope and method	In figure 5, the legend contains a box "life cycle stage without environmental aspect". This box is not included in figure, so why in legend?	The box is now deleted from the figure	ok
5	Goal, scope and method	Allocation is done according to the PP allocation method, which is in line with the ISO-standard.	-	
6	Goal, scope and method	Table 1 states that disposal has been excluded. Does this include waste-flows during production as well or only in end of life? Please specify.	"In end-of-life" is added to clarify.	ok
7	Goal, scope and method	On p. 13, the following is stated "Unless there is a reason to assume otherwise (e.g., use of a highly hazardous chemical), materials that are less than 1% by mass are assumed to also contribute less than 1% of the environmental impact." This is a very rough assumption, and in many cases the mass of different materials is not linear with the environmental impact. Further, there is no information on what energy flows or materials within the assessed life-cycle stages have been excluded based on this criterion.	This section has been removed. The flow that has been neglected for the specific data is the water consumption in the manufacturing of the film. This has been specified in the LCI section.	ok
	Goal, scope and method	In the end of section 2.2.6 it is stated that waste is allocated in accordance	Added: There has been no environmental	ok

No.	Section	Review comment	Answer	Acceptance of revision
		with the method "Allocation-cut-off". Which waste flows does this refer to?	aspects to apply the method to.	
8	Goal, scope and method	In section 2.2.11, the classification terms A2, A3 etc. (from the EN15804-standard - PCR for building materials) are used for the different life cycle phases. If these terms are to be used, they should be introduced previously, for example in section 2.2.3, with a reference to the standard.	Removed A2 and A3 and kept the text about which life cycle phase that it corresponds to since the EN standard is not used in the report.	ok
9	Goal, scope and method	In table 3, data quality assessment, reference is made to requirements in EN15804 is met. However, the standard is not mentioned anywhere else in report. Please specify somewhere in chapter 2 to which extent EN15804 is followed, and refer to the standard in reference list.	It was supposed to be ISO 14044 and has now been changed to ISO 14044.	ok
10	Goal, scope and method	Regarding the inclusion of carbon sequestration: the validity of sequestration is highly dependent on whether the product is recycled or incinerated by the end of life. How likely is it that the stretch film is recycled by the end of life? What do statistics say? To underline this, I would recommend to present results both including and excluding carbon sequestration.	The results are now calculated excluding carbon sequestration due to the choice of system boundary for the study.	ok
11	Goal, scope and method	The documentation in report is satisfactory regarding consistency and reproducibility of the methods used for data collection and data treatment.	-	
12	LCI	In section 2.2.10 it says that "all data concerning material, energy and waste are specifically modelled for the prerequisites of the manufacturing facility and the technology that are used". However, it is hard to find information about waste flows in production. Is there no other production	According to Doxa there is no waste from the process other than the spillage of LLDPE. Everything is consumed in the process.	ok

No.	Section	Review comment	Answer	Acceptance of revision
		spillage than the LLDPE described on p. 23?		
13	LCI	On p. 15 it is said that “The following requirements are used (see below) for all the central LCI data.” What does central data encompass?	Resolved	ok
14	LCI	There seems to be a deviation in the weight of the final product and weight of materials used to produce it. Weight per m2 of DX 20 micron (table 4): 0,0183 Weight of raw materials used for 1 m2 of DX 20 (table 5): 0,0173 Input materials only add up to 94 % of final material weight. The sum of materials used for production should be at least as big as the product weight. If it includes material spillage in production, it should be bigger. Is it due to cut-offs? For Doxess, this deviation is smaller, and input materials add up to 97 % of product weight. However, also this deviation should be explained. Please check this and explain deviation.	There has been a mistake in the presentation of the numbers. The entire chapter 3 has been rearranged to represent the new declared unit.	ok
15	LCI	Have the data for production of LLDPE from Dow been reviewed in any way?	The data from Dow is not third party verified. We have discussed this issue with Doxa and Dow. A section has been added that addresses the uncertainty of this type of data in the discussion.	ok
16	LCI	Packaging of DX. In table 13, it says that 0,180 kg of stretch film (DX 23 micron) is used per m2 of product. It seems unlikely that this amount of stretch-film is used for packaging of	This number was wrong. Due to the change in declared unit, it has now been corrected based on	ok

No.	Section	Review comment	Answer	Acceptance of revision
		0,0183 of product (1m2). Please explain misunderstanding.	new information from Doxa.	
17	LCI	Same question regarding packaging for Doxess in table 19.	Answered above	ok
18	Data calculations	Sample checks have been done for some of the results. No further deviations found.	-	
19	Life cycle impact assessment (LCIA)	Relevant choice of LCIA method and impact categories.	-	
20	LCIA	Is it correct that without carbon sequestration, the production of bio-based PE gives higher GWP than the fossil alternative? It would be interesting to elaborate this more.	Yes, this is true. It is now included in the discussion.	Good that this is added in discussion. As you recommend, a further investigation would be interesting. Could be interesting to show total results with Ecoinvent data for the raw material production instead of the dow-data (just a recommendation, not a requirement for approval of report).
21	Results	The question regarding amounts of packaging needs to be resolved before a proper review of results can be made.	It has now been resolved	ok

No.	Section	Review comment	Answer	Acceptance of revision
		I question the reasonability of results show in figures 20 and 21, where packaging of the product gives higher CO2 emissions than the product itself.		
22	Interpretation	Good and relevant discussion regarding specific data in comparison to general data.	-	
23	Redactional	On p. 13 a reference is made to Wernet et al., 2016, this reference is not found in the reference list.	Added to reference list.	ok, however reference in main report has been removed.
24	Redactional	After review, change text under 2.2.13 to past tense.	Done.	ok
25	Redactional	Reference on page 20 (Helling, R., 2020) is missing in reference list.	Added to reference list.	ok