B 2392
September 2020

ProScale assessment within life cycle assessment on utility poles

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Funded by: Energiforsk AB and SIVL
Report number B2392
ISBN 978-91-7883-214-9
Edition: Only available as PDF for individual printing.

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Summary

This report is one out of two deliverables of a research project funded by Energiforsk and the SIVL foundation carried out by IVL Swedish Environmental Research Institute in 2019 and 2020. In this report the outcome of the ProScale assessment is documented. Both reports are published on ivl.se (report number B2392 and B2393) and on Energiforsk.se (report number 2020:693 and 2020:694).

The ProScale methodology can in a simplified way be described using Equation 1, where: PSS denotes the ProScale Score; HF is the Hazard Factor for a substance, ECF is the Exposure Concentration Factor, PHF is a Person-Hour Factor and MF is the Mass Flow. ProScale scores are derived separately for inhalative, oral and dermal exposure routes.

$$PSS = HF \times ECF \times PHF \times MF \qquad \text{Eq. 1}$$

The goal of this study is to assess the direct human toxicity potential resulting from the production of utility poles by using the ProScale method in life cycle assessment (LCA) and identify which processes in the life cycle of the utility poles that have the largest contribution to both inhalation and dermal direct human toxicity potential (dominance analysis). Three utility poles are evaluated using ProScale: wood-based pole impregnated with creosote, composite pole and wood pole encapsulated with plastic.

The assessment is focusing on the production of the utility poles and the upstream processes for producing the raw materials in the poles. The ProScale method, as it is used today, considers the toxicity potential of material and product flows in the processes, and not elementary flows such as emissions that emerge from unit processes. The possibility of including emissions in the assessment and how that affects the results are aspects briefly discussed in one or two examples.

The ProScale assessment of the wood pole impregnated with creosote shows that the process of impregnating the pole is the activity that contributes most to the score for both inhalation and dermal. For the composite pole, the production of polyethylene and the production of polyester are the two activities that contributes most to the total score for inhalation and for dermal, the production of glass fibre also contributes significantly to the score. The results for the wood pole covered with HDPE shows that the production of polyethylene is the activity contributing most to the total score for inhalation and dermal.

The possibility of including emissions in the assessment and how that could affect the ProScale score was tested for turning of wood and drying of wood. The results show that including emissions would have an insignificant impact on the total ProScale score. However, the analysis shows that it is possible to include emissions in the assessment.

The procedure of making ProScale assessment is working, from collecting data and using the web-tool, to allocate the PSU and calculating the total score per functional unit. A database of default ProScale values for several materials and chemicals have been developed and more unit processes are planned to be created within the near future. Also, a development project of making the ProScale assessment available for LCA practitioner is planned, to enable making assessments on their own, and also contribute to the database by submitting performed assessments for new processes and products.

Abbreviations

PSP	ProScale for product
PSU	ProScale for unit process
HF	Hazard factor
ECF	Exposure Concentration Factor
PHF	Person-Hours Factor
MF	Mass Flow

1 Introduction

Increasingly, various stakeholders require and request information on toxicity aspects of products beyond regulatory requirements for chemicals, e.g. in the framework of Life Cycle Assessment ("LCA"). There is currently no methodology available which fully satisfies the requirements of the industry and other stakeholders in this context, but requirements are often based on lists for priority substances without evaluating their risk in specific applications. This calls for a performance-based indicator that can be used and communicated within LCA's, Environmental Product Declarations ("EPD's") and Product Environmental Footprints ("PEF's").

1.1 About this report

This report is one out of two deliverables of a research project funded by Energiforsk and the SIVL foundation carried out by IVL Swedish Environmental Research Institute in 2019 and 2020. The project comprises an LCA and a parallel ProScale assessment of utility poles. In this report the outcome of the ProScale assessment is documented.

1.2 What is ProScale?

The ProScale™ method has been developed during 2016-17 in an industry consortium with expertise both from the Life cycle assessment and Risk assessment areas [1,2], the founding members being BASF, Covestro, Deutsche Bauchemie, DSM, IVL, Kingspan and Solvay. The purpose of the development was to achieve an easy-to-use method for assessing direct-exposure related Human Toxicity Potentials for product systems (LCA perspective), ideally compatible with Product Environmental Footprint (PEF). For clarity it should be stressed that only direct Human Toxicity Potential is covered by the method, although similar hazard statements (called H-phrase), based approaches have been developed for eco-toxicity [3]. For indirect human toxicity, and for eco-toxicity, other approaches such as the USETox method are available [4]. The ProScale methodology can in a simplified way be described using Equation 1, where: PSS denotes the ProScale Score; HF is the Hazard Factor for a substance, derived based on substances classification in the GHS/CLP classification system, reflecting health effect severity and potency based on H-phrase and OEL or DNEL; ECF is the Exposure Concentration Factor, and describes the exposure of a substance based on exposure modelling using a tier 1 exposure model (Based on ECETOC TRA, v3); PHF is a Person-Hour Factor describing the person-hours of work needed per unit output or input of a process (product or service); and MF is the Mass Flow, describing the amount of a substance needed to produce a product (kg per functional unit). ProScale scores are derived separately for inhalative, oral and dermal exposure routes. More information about the ProScale method is found in the guiding document, A life cycle-oriented method to assess toxicological potentials of product systems [2].

$$PSS = HF \times ECF \times PHF \times MF \qquad \text{Eq. 1}$$

2 Goal and scope

In this chapter, the goal and scope of the study is defined and explained. The primary objectives of the study are listed, and the scope of the project is described. This chapter helps the reader to understand the results by reviewing the system studied, system boundaries, key assumptions and limitations.

2.1 Goal

The goal of this study is to:

- assess the direct human toxicity potential resulting from the production of utility poles by using the ProScale method in life cycle assessment (LCA).
- Identify which processes in the life cycle of the utility poles that have the largest contribution to both inhalation and dermal direct human toxicity potential (dominance analysis).

The result is intended to enlighten how the ProScale method works and how it can be integrated into LCA. Furthermore, the result should indicate which processes that have the largest contribution to both inhalation and dermal direct human toxicity potential. The result is intended to be used by LCA practitioners.

2.2 Scope

The study aims at investigating the direct human toxicity potential, for both inhalation and dermal, using ProScale, for three utility poles:

- Wood based pole impregnated with creosote produced by Rundvirke
- Composite pole produced by Jerol
- Wood pole encapsulated with plastic produced by Wopas

The assessment is focusing on the production of the utility poles and the upstream processes for producing the raw materials in the poles. The ProScale method is novel in that sense that assessments for all individual unit processes have to be developed. Thus, the scope of the project is limited to include the production of the poles and does not include the use phase, potentially different service and maintenance need and end-of-life management. Additionally, and for this reason, the aim of the study is not to compare the toxicity potential from utility poles. Instead the ProScale score is presented for each pole separately, and for each pole type, distributed on different parts or segments of the value chain.

The assessment of the production of the utility poles is based on the information and data obtained from the utility pole suppliers. The assessment of production of raw materials is based on information and data mainly from literature.

By applying the ProScale method in a case study, the study aims at developing the applicability of the ProScale method in LCA and gain working experience in using ProScale. The long term aim is to integrate ProScale fully in LCA, but the current focus is on the ProScale procedure, the web-tool, how to allocate the ProScale score for unit processes (PSU) between products (if multiple outputs) and how to calculate the total ProScale score for products (PSP). Also, the method, as it is used today, considers the toxicity potential of material and product flows in the processes, and not elementary flows such as emissions that emerge from unit processes. The possibility of including emissions in the assessment and how that affects the results are aspects briefly discussed in one or two examples.

2.2.1 Type of LCA

The study is an attributional LCA, where the direct human toxicity potential is assessed for the utility poles.

2.2.2 Functional unit

The reference flow is the production of one 12 meters utility pole (N12). The lifetime of the utility poles is not considered as a parameter since the use phase is not included in the study.

2.2.3 Studied product systems

The studied products systems are described in detail below. The flowcharts describe which processes that have been included in the assessment.

Wood based pole impregnated with creosote (Rundvirke)

The utility pole produced by Rundvirke is wood-based impregnated with creosote. The considered life cycle stages, from a cradle to grave perspective, for the pole, are shown in Figure 1. The creosote is produced from coal and the impregnation of the wood pole takes place at the manufacturing site. Site specific data were collected from Rundvirke for the impregnation of the pole. The planting of the seeds at the plantation, drying and debarking, are expected to have a limited effect on human health and therefore not included. The reason for assuming limited effects on human health for these processes is that no chemicals are used. For instance, it is assumed that no toxic pesticides are used during the growth phase of the tree.

During the use phase, the impregnation on the pole leaches and thus could affect humans in the surrounding area. The drying of impregnated poles, installation of poles, use phase, deconstruction and waste management are not included in this assessment since the scope based on resources available was defined as cradle to gate until and including production of the pole.

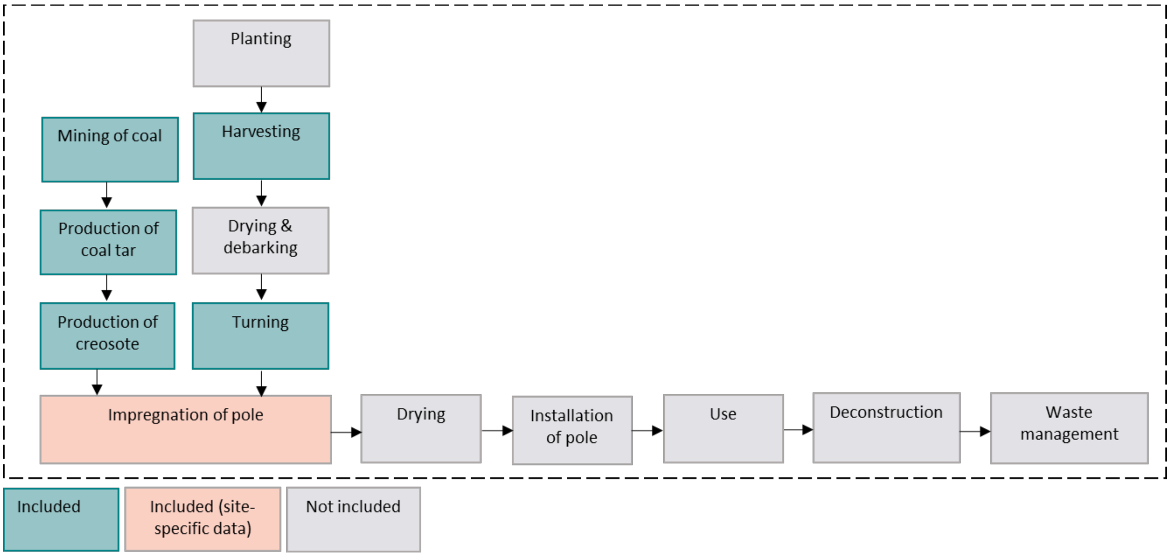


Figure 1: Overview of the life cycle of the wood based pole impregnated with creosote. The green boxes are the processes included in the assessment, the pink boxes are the process with site-specific data and included the assessment, while the grey boxes are the processes not included.

Composite pole (Jerol)

The utility pole produced by Jerol is a polymer composite pole, made up of glass-fibre reinforced polyester, covered with a layer of polyethylene. The considered life cycle stages for the pole, from a cradle to grave perspective, are shown in Figure 2. The upstream processes for all the materials are included in the assessment. Site specific data for the production of the composite pole were collected from Jerol. The installation use and deconstruction of the pole were outside the cradle-to-gate scope, but are anyway also expected to have a limited effect on human health. The reason for assuming limited effects on human health for these processes is that no chemicals are used or leached from the poles during the use. According to Erlandsson (2011), it is reasonable to assume that emissions leached from the pole are negligible since the quality of the polyethylene is the same as for the ethylene used in drinking water pipes [5].

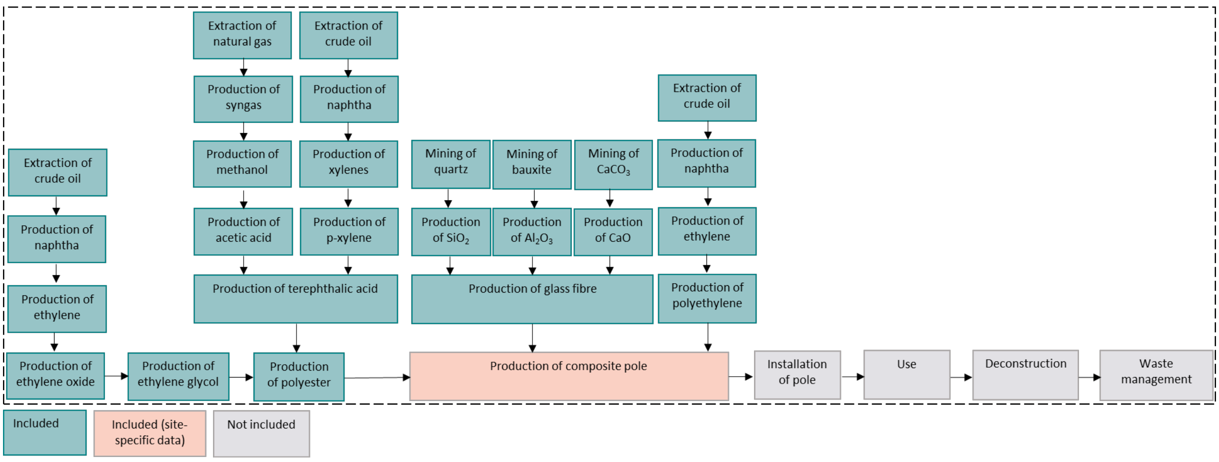


Figure 2: Overview of the life cycle of the composite pole. The green boxes are the processes included in the assessment, the pink boxes are the process with site-specific data and included the assessment, while the grey boxes are the processes not included.

Wood pole encapsulated with plastic (Wopas)

The utility pole produced by Wopas is a wood-based pole covered with a layer of polyethylene. The considered life cycle stages for the pole, from a cradle to grave perspective, are shown in Figure 3. The upstream processes for polyethylene (PE) are included in the assessment. All PE is assumed to be from virgin material in this assessment. Site-specific data are collected from Wopas for the turning, drying and the construction of the pole. The processes installation, use, deconstruction and waste management of the pole are not included as they are outside the cradle-to-gate scope, and they are also expected to have a limited effect on human health. The reason for assuming limited effects on human health for these processes is that no chemicals are used or leached from the pole during the use.

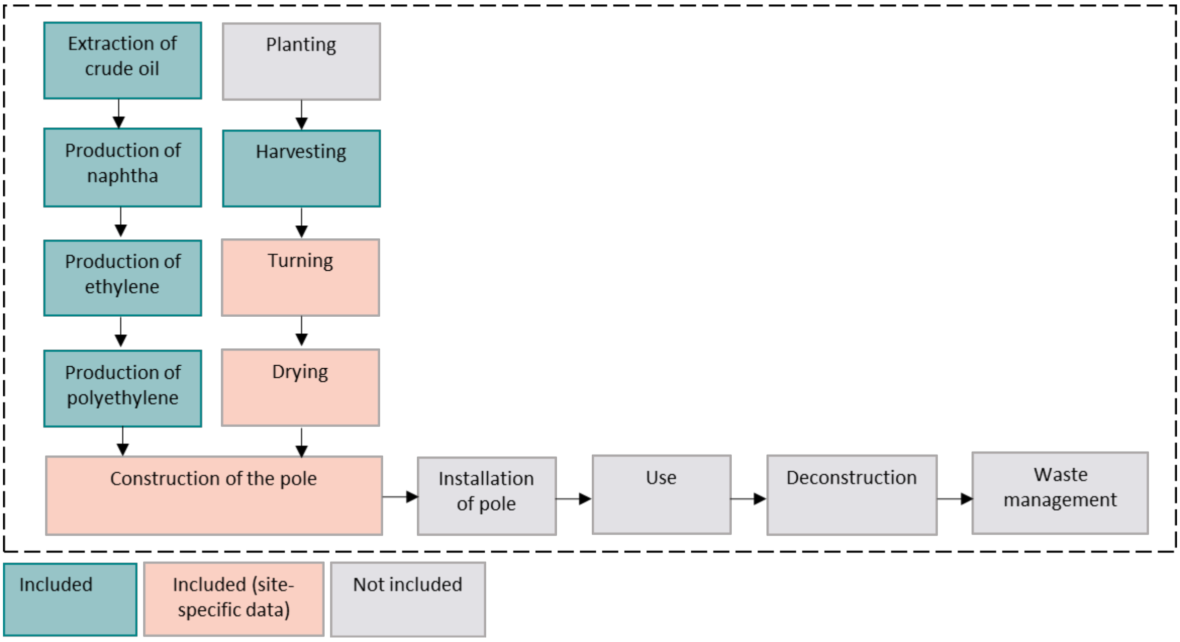


Figure 3: Overview of the life cycle of the wood pole encapsulated with plastic. The green boxes are the processes included in the assessment, the pink boxes are the process with site-specific data and included the assessment, while the grey boxes are the processes not included.

2.2.4 System boundaries

In this section the system boundaries applied in the LCA are specified. Aspects such as boundaries towards nature and geographical boundaries, as well as methodology aspects concerning system expansion and allocation are defined and explained.

2.2.4.1 Boundaries towards nature

This study is a cradle to gate assessment, where the production of most of the raw materials and the production of the poles are included. The production of fuel and generation of electricity is not included because of time constraints. For the same reason, the transportation of the raw material and products are not included.

At this stage, the assessment considers the flow of material and products within the system as this is the basis for the ProScale assessment model, rather than emissions which are the typical starting point for conventional impact assessment in LCA.

2.2.4.2 Geographical boundaries

The definition of the geographical boundaries in the assessment is unimportant since the stages in the life cycle that are influenced by geographical position are not considered, for instance transport, electricity generation and consumption and waste management.

2.2.4.3 System expansion

System expansion is not applied in this study.

2.2.4.4 Allocation

In a unit process with multiple outputs, for example the steam cracking process, allocation of the ProScale score of the unit process (PSU) is needed. Conventional options are allocation based on mass, economy, or energy. In this study, the ProScale score for the unit process (PSU) is divided by the total mass of all outputs, meaning that the cracker process contribution to the product score for all different products from (in this case) the cracker will be the same for each kg of output.

2.2.5 Limitations

The outcome of the study is influenced by limitations and assumptions made in the assessment. The main limitations of the study are listed below:

- Material and product flows are considered but not elementary flows such as emissions from the processes into the environment.
- The assessment is in the system boundary cradle to gate.
- The generation of electricity is not included.
- Extraction and processing of fuel used in the processes are not included.
- The transportation of material and fuel are not included.

3 Life cycle inventory analysis

This section gives an overview of the data collection process and the information collected and used in the analysis. The collected data are inputs and outputs of material, chemicals, products and energy (fuel and electricity), which is complemented with ProScale specific data.

Site specific data of inputs and outputs were collected from the utility pole producers. Generic data for upstream processes were collected from literature, for example Plastic Europe's eco-profiles. The mass- and energy flows are together with ProScale specific data documented in a data collection template specifically developed for ProScale assessments, see a figure of the template in Appendix A: Data collection template. Thereafter, all of the data is inserted to a webtool used for making ProScale assessments.

ProScale specific data are needed to determine the Hazard Factor (HF), the Exposure Concentration Factor (ECF) and Person-Hours Factor (PF). Data collected to determine the HF are hazard classifications (H-phrases) of substances and materials and occupational exposure limits (EOLs). Hazard classifications and OELs are usually found at the European Chemicals Agency (ECHA). The data and information needed to determine the ECF are technical descriptions of the processes studied and a substance or material´s fugacity (likelihood of becoming airborne). The technical description is needed to translate the studied process into a generic process category (PROC). The fugacity for a liquid is determined by its vapors pressure, while the fugacity for a solid is determined by its dustiness. The PF is the number of person-hours worked per amount of production.

4 Result and discussion

In this chapter, the result of the study is presented. At first, ProScale scores, both inhalation and dermal, for several materials, chemicals and processes are presented. After that, the dominance analysis for the three utility poles is presented and discussed.

4.1 ProScale of product and unit process

ProScale scores were created for materials and chemicals within the value chain, cradle-to-gate (ctg), and unit processes (up), for the three utility poles. The results showed in Table 1 are aggerated ProScale scores of products (PSPs), from cradle-to-gate, and scores for ProScale of unit processes (PSUs). The values showed in the table should be read with caution, being preliminary and not independently reviewed yet.

Table 1: ProScale score (PS), both inhalation and dermal, for some products (PSP) and processes (PSU) included in the study.

Product	PS Inhalation [PS per kg]	PS Dermal [PS per kg]
Coal tar (*)	3.9	2.6E-03
Creosote (*)	8.1	9.5E-02
Ethylene (*)	100.3	9.1
Ethylene glycol (*)	64.9	5.9
Acetic acid (*)	3.5E-01	2.3E-03
P-xylene (*)	21.9	2.3
Terephthalic acid (**)	6.6E-05	1.0E-04
Polyester (*)	139	8.5
Glass fibre (*)	3.2	2.1
Polyethylene (*)	100.7	9.1

(*) PSP= ProScale Score of products, i.e. the full value chain from raw material extraction up until the named product are included.

(**) PSU = ProScale Score for unit process, i.e. only the specific production process for the named product is included

The scores for inhalation range from 10^{-5} to 100 and the most significant material, with the highest score, is polyester which is caused by the production of ethylene and the unit process for producing polyester. The reason for the high value for ethylene is because ethylene is produced from Naphtha. Naphtha has an OEL of 3.25 mg/m^3 and has the highest hazard classification (H350).

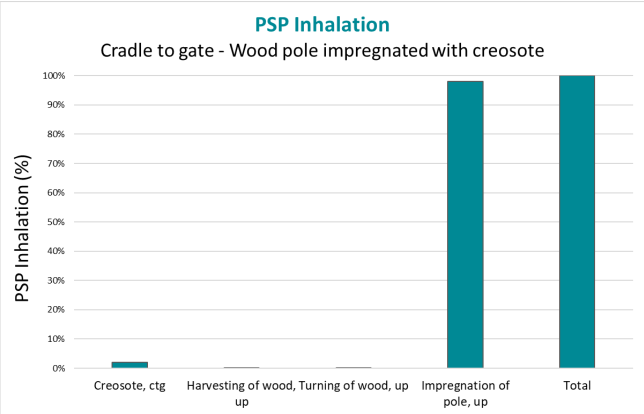
The ProScale scores for dermal range from 10^{-4} to 10 and the most significant material, with the highest score, is ethylene. The reason for the high value is the same as for the score for inhalation.

4.2 Dominance analysis

The result of the dominance analysis for the three utility poles are presented below. The results are presented separately for the poles and in percentage of the total ProScale score.

4.2.1 Wood pole impregnated with creosote

The cradle-to-gate ProScale results, both inhalation and dermal, for the wood pole impregnated with creosote are shown in figure 4. The results show that the activity contributing mostly to the total ProScale score, for both inhalation and dermal, is the impregnation of the pole. The wood pole is impregnated with creosote which has an OEL of 0.14 mg/m^3 and has the highest hazard classification (H350). The harvesting and turning of wood have an insignificant impact on the total score.



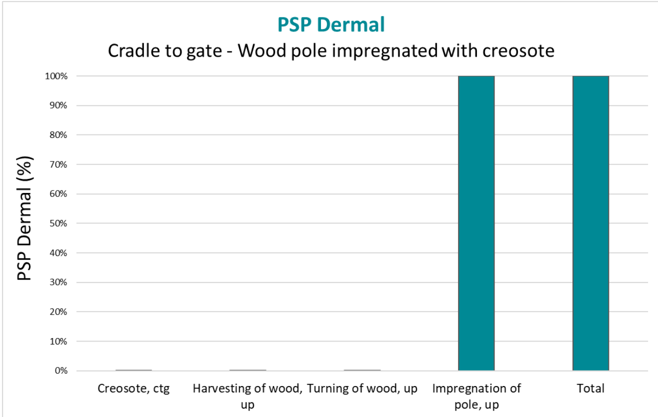


Figure 4: ProScale result for inhalation (left) and dermal (right) for the wood utility pole impregnated with creosote.

As mentioned in the goal and scope, emissions from processing are outside the scope of the study. But, emissions of wood dust from the turning could possibly influence the result. Wood dust has an OEL of 2 mg/m^3 and has the highest hazard classification (H350). If comparing the amount of creosote used during the impregnation with an estimation of how much wood dust that could possibly be released when turning, the amount of creosote is huge in comparison. Meaning that the impregnation of the pole still would contribute most to the total score.

4.2.2 Composite pole

The cradle-to-gate ProScale results, both inhalation and dermal, for the composite pole are shown in Figure 5. The results show that the activities contributing mostly to the total ProScale score, for inhalation are the production of polyester and polyethylene. The production of glass fibre contributes little to the total score for inhalation. The production of the pole has insignificant contribution to the total score for inhalation.

The composite pole consists of 57 % glass fibre, 30 % polyester and 13 % polyethylene. The PSP inhalation for polyester and polyethylene are so much higher than the PSP score for glass fibre resulting in a large contribution for the PSP inhalation for the composite pole (see table 1). This results in that the activities contributing most are the production of polyester and polyethylene even though the utility pole consists of mostly glass fibre.

The ProScale results for dermal shows that the activity contributing most to the total score is the production of the raw materials in the pole. The production of the composite pole has insignificant contribution to the total score for dermal.

The difference in ProScale score for dermal for polyester, glass fibre and polyethylene is smaller compare to the difference in ProScale score for inhalation (see Table 1). The small difference results in that the glass fibre production contributes most to the total score for dermal because the pole consists of 57 % glass fibre.

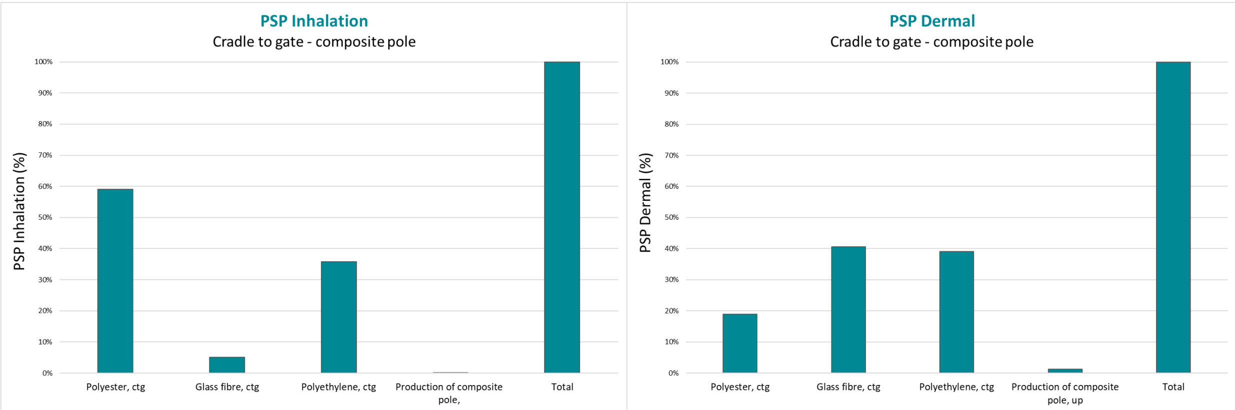


Figure 5: ProScale result for inhalation (left) and dermal (right) for the composite utility pole.

4.2.3 Wood pole encapsulated with plastic

The cradle-to-gate ProScale results, both inhalation and dermal, for the wood poles covered with HDPE are shown in figure 6. The results show that the activity contributing almost 100 % to the total ProScale score, for both inhalation and dermal, is the production of polyethylene.

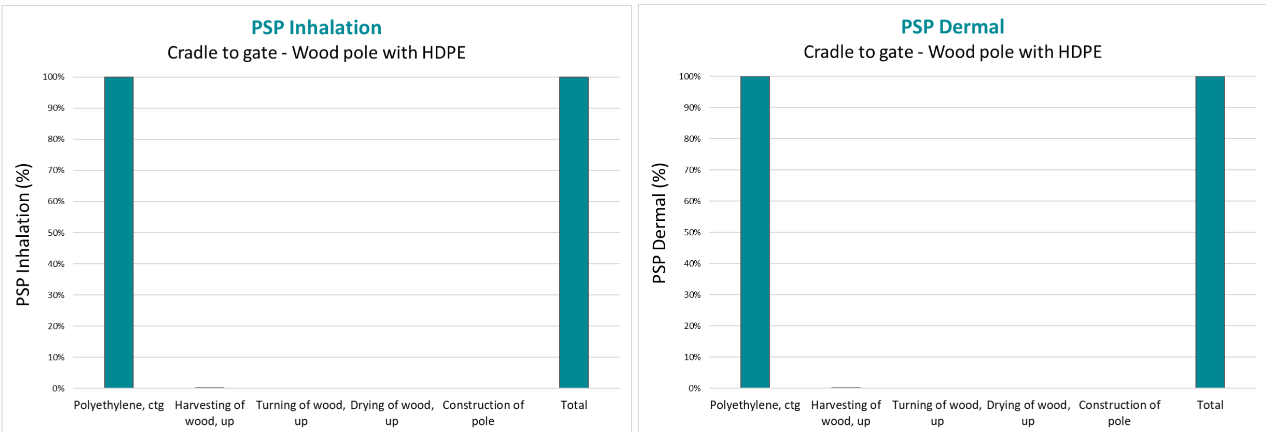


Figure 6: ProScale result for inhalation (left) and dermal (right) for the composite utility pole.

Turning of wood results in emissions of wood dust (as discussed in the wood pole impregnated with creosote). During drying of wood, volatile organic substances, especially terpenes, are released. Terpenes have an OEL of 150 mg/m3 and have the following hazard classifications H304, H315 and H317 [6]. These H-phrases falls in the ProScale hazard class toxic [2]. Several studies have been conducted to find the amount of terpene released during drying of wood. In a study by Granström (2005), the amount of terpene released during drying of wood is enlighten by summarizing the results from several studies. The study shows that the terpene emissions ranges from 20-2000 mg/kg oven-dry wood and the emissions are highly dependent on wood type [7]. Taking that into consideration, the amount of terpene emissions is low in comparison to the material flows assessed in this study. Meaning that the production of polyethylene still would contribute most to the total score even if terpene emissions were to be considered.

5 Conclusion and outlook

The overall goal of this study was to assess the direct human toxicity potentials resulting from the production of utility poles by using the ProScale method in LCA. The ProScale assessment of the utility poles presented in the results showed which processes in the life cycle of the utility poles that have the largest contribution to both inhalation and dermal direct human toxicity potentials.

The ProScale assessment of the wood pole impregnated with creosote shows that the process of impregnating the pole is the activity that contributes most to the score for both inhalation and dermal. For the composite pole, the production of polyethylene and the production of polyester are the two activities that contributes most to the total score for inhalation and for dermal, the production of glass fibre also contributes significantly to the score. The results for the wood pole covered with HDPE shows that the production of polyethylene is the activity contributing most to the total score for inhalation and dermal.

The possibility of including emissions in the assessment and how that could affect the ProScale score was tested for turning of wood and drying of wood. The results show that including emissions would have an insignificant impact on the total ProScale score. However, the analysis shows that it is possible to include emissions in the assessment.

Further, the aim of the study was to develop the applicability of ProScale in LCA. The results in this study shows that ProScale is a functioning method to integrate exposure toxicity potential in LCA. ProScale could be used as a complement to the common method used in LCA to assess human toxicity potentials.

The procedure of making ProScale assessment is working, from collecting data and using the web-tool, to allocate the PSU and calculating the total score per functional unit. A database of default ProScale values for several materials and chemicals have been developed and more unit processes are planned to be created within the near future. Also, a development project of making the ProScale assessment available for LCA practitioner is planned, to enable making assessments on their own, and also contribute to the database by submitting performed assessments for new processes and products.

6 References

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Appendix A: Data collection template

Flows

Input data					Fugacity		ProScale Output score	
Flow type	CAS-Nr (if any)	ProScale Id Nr (if any)	H300-phrases	OEL / DNEL (mg/m3)	Vapour pressure (20-25 degC) (kPa) /Dustiness	Flow amount X/FU (kg or MJ)	Inhal.	Derm.
Inflows								
Outflows								
Internal flows (recycled in process)								
PSU								
Inhal.								
Derm.								

Assigned PROC

PROC XX

Motivation:

Assigned PHF

PHF:

Process contribution to product score

Allocation of PSU conducted on mass basis. These values should be used when aggregating PSU for the total value chain for a product.

Valuable outflow	PS Inhalation (PS/FU)	PS Dermal (PS/FU)

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