Impact study of the creosote ban on power grid projects

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Abstract

Throughout the world, a vast majority of electric utility poles are made of wood. To increase the service life of these poles and improve their durability against various types of deterioration (insects, bad weather, and humidity), they are impregnated with fungicides and insecticides that are often dangerous for human health and the environment.

The most common of these is creosote, a product derived from the manufacture of steel which is made from coal.

Its impact on human health (it is carcinogenic, mutagenic and reprotoxic) and on the environment (it is very toxic for aquatic organisms) prompted the European Commission to ban it.

This decision is part of a series of regulations aimed at stopping the use of chemicals that are too dangerous for humans and the environment.

Therefore, the issue of alternative solutions for manufacturing power poles arises for power grid managers as well as for development banks which, like AFD, fund the construction of power grids.

A variety of wood treatments, all with varying degrees of human health and environmental hazards, are available and make it possible to manufacture economical, easily installed poles made from wood (a natural, renewable resource found in many regions) with a rather favorable life cycle balance.

Steel poles are lightweight, can be easily installed and transported, are strong but can be subject to corrosion, are expensive, are taxing on our metal resources, and cannot be easily manufactured locally.

Concrete poles can be easily manufactured in many countries, are reasonably priced and extremely strong, but they are heavy (and therefore difficult to transport), may be sensitive to certain harsh climates, and have an unfavorable life-cycle CO_2 balance.

Composite poles are light, very strong, have a long service life but are very expensive and have a rather average LCA.

This report shows that choosing a manufacturing technology for electric utility poles involves choosing between:

- **economic or CO_2 emission reduction goals** in favor of treated wood poles.

- **or human health and environmental protection goals** in favor of steel, wood, or composite material poles.

Power grid managers must take a nuanced approach depending on the location of each pole, as certain parameters will prohibit or make it difficult to use certain technologies: the available transmission infrastructure, the climate, the type of soil in which the pole is installed, the exposure to fire, storms or floods, the risk of vandalism and degradation, or the desire to produce them locally.

Each party will have to make and refine their choices to achieve the best possible compromise between the cost of the grid (in the sense of full cost of ownership), the impacts on human health and the environment, and controlling CO_2 emissions over the service life of the poles.

Glossary

CAS The CAS number of a chemical substance is its registration number with the American Chemical Abstracts Service (CAS) worldwide database. This database currently lists nearly 150 million substances.

CCA CCA is a mixture of copper, chromium and arsenic.

CLP European CLP Regulation on classification, labeling and packaging of chemicals and mixtures.

CMR Some chemicals, alone or in mixtures, can have various harmful effects on human health. Some of them can be carcinogenic, mutagenic, or toxic for reproduction; they are then called CMRs.

ECHA European Chemicals Agency.

EPA The Environmental Protection Agency is the U.S. government agency that oversees the environment.

FIFRA The Federal Insecticide, Fungicide, and Rodenticide Act is a U.S. federal law that provides the basis for U.S. pesticide regulation for protecting people and the environment.

Half-life Half-life is the time it takes for a substance to lose half its physiological activity.

IARC The International Agency for Research on Cancer is an intergovernmental research agency founded by the World Health Organization (WHO).

LCA The Life Cycle Assessment (LCA) is a standardized method (ISO 14040) to conduct a multi-criteria environmental assessment of a product, an organization, or a system, cumulated over its entire life cycle.

Leaching refers to all means of extraction of soluble products by a solvent, starting with water circulating in the soil or in a substrate containing toxic products.

PAHs Polycyclic aromatic hydrocarbons (PAHs) are a subfamily of aromatic hydrocarbons (made up of carbon and hydrogen atoms) that have been studied extensively because of the toxicity of their constituent substances.

PBT A substance is said to be PBT if it is persistent, bioaccumulative, and toxic. For example, persistent organic pollutants (POPs) are PBTs.

RAC The Risk Assessment Committee prepares the opinions of ECHA on the risks of substances to human health and the environment as part of REACH and CLP procedures: the final decisions are made by the European Commission.

REACH Registration, Evaluation, Authorization and Restriction of Chemicals (EU Regulation).

SEAC The Socio-Economic Analysis Committee prepares the opinions of ECHA on the socio-economic impact of potential legislative measures on chemicals as part of REACH procedures: the final decisions are made by the European Commission.

Introduction

With increasing regulatory pressure on aspects of human health and environmental protection issues, it is entirely legitimate for major public investors such as Agence française de développement (AFD) to seek to measure the impact on the projects they fund.

The recent European ban on creosote as a treatment for utility poles has led AFD to explore possible alternatives for manufacturing them. The purpose of this document is to answer this question.

This document is the most comprehensive, accurate summary possible of the data currently published that is freely available.

In terms of analyzing the chemicals used to treat utility poles, this document provides a well organized reading of the official data published, in particular by the European and American public authorities. However, it is not a document written by expert chemists who are qualified to give an informed opinion on all the substances mentioned.

1. What is creosote and why is it used in power poles?

1.1. Creosote

Creosote is not a clearly defined product but rather a family of products. This name refers to various oils having a complex composition that are extracted from tars resulting from distilling plant-derived materials (plants and wood) or minerals (coal).

The most common type of creosote is coal-tar creosote which will be discussed in this document. **This product does not occur naturally. It is an industrial product derived from coal.**

For the sake of simplicity, we will henceforth use the term "**creosote**" to refer to coal-tar creosote.

Creosote comes from distilling tars produced in a coke oven at temperatures between 200 and 400°C. Its composition is always complex because it is made up of 150 to 300 different elements and varies depending on the origin of the coal and the distillation method.

It is often sold mixed with oil or a solvent, which gives it the appearance of a dark oily liquid with a characteristic smell.

Creosote is a registered substance by the two main chemical management agencies: the Environmental Protection Agency (EPA) in the United States and the European Chemicals Agency (ECHA) in Europe.

Creosote	**ECHA**	100,029,468	**CAS**	8001-58-9

1.2. Creosote: a biocide with a long history of use in power pole protection

Since the origin of electric utility poles in the 19th century, the most natural and obvious material for making them has been wood.

As we will see repeatedly in this document, wood has multiple advantages that justified its use in the past and is why it continues to dominate manufacturing today:

- wood is abundantly available in countless countries.
- wood is an inexpensive material.
- wood poles are easy to manufacture and install, mainly due to their weight, which is light enough to be not very constraining.

Today, the manufacturing of power poles meets demanding but accessible standards: the vast majority of specialized sawmills can produce compliant raw poles.

On the other hand, wood poles are subject to multiple stresses, especially in hot and humid environments:

- by xylophagous insects, especially termites.
- by lignivorous fungi.
- by woodpeckers.

For the past hundred years, the challenge of extending the life of these poles, avoiding their wear and tear, and having to replace them frequently, has led to protecting the wood against most of these stresses. The service life of the poles was thus extended by 5 to 10 years, varying from 40 to 60 years depending on the wood species and the climate.

Creosote and copper sulfate are two of the pesticides, fungicides, and sporicides that have been used for a long time to treat utility poles.

Because of its excellent properties, creosote has also long been used to protect:

- railroad ties.
- electric and telegraph poles.
- marine pilings.

With creosote treatment, wood poles can withstand more constant moisture, can be driven directly into the ground, are protected from insects, including termites, and are protected from mold.

2. The disadvantages of creosote

The European Commission, via ECHA, and the United States, via the EPA, have conducted and shared numerous studies on creosote. Their conclusions converge in all respects.

2.1. Creosote, a hazard for people

Creosote is a mixture of several hundred compounds that belong to various groups of substances:

- polycyclic aromatic hydrocarbons (PAHs), which can make up to 85% of creosote.
- phenols.
- heterocyclic compounds.
- aromatic amines.

Many of these substances are toxic to humans, especially PAHs, which naturally make up coal, but are also produced by the incomplete combustion of fuels or wood.

The most important toxic PAHs found in creosote are:

- acenaphthene: used as a basis for herbicides.
- acenaphthylene: used as a basis for herbicides and plastics.
- anthracene: used as a basis for insecticides and wood preservatives - classified as "PBT" (persistent, bioaccumulative and toxic).
- benzanthracene: listed as a carcinogen by the International Agency for Research on Cancer (IARC).
- benzopyrene: persistent air pollutant, bioaccumulated by some marine animals - classified as "Very PBT".
- benzo[k]fluoranthene: carcinogenic substance highly toxic to aquatic organisms.
- fluoranthene: included in the IARC list of carcinogens - classified as "Very PBT".
- fluorene: used as a basis for manufacturing pesticides and plastics.
- naphthalene: used as a basis for manufacturing insecticides and resins.
- phenanthrene: one of the persistent organic pollutants (POPs) - classified as "Very PBT".

Due to its complex composition, the available studies on creosote are scientifically insufficient to prove its effects on human health. The current literature available on creosote is mainly based on studies performed on its main components.

The human health impacts proven for the components of creosote are assumed to be the same or similar for creosote. This generalization of the conclusions calls for caution. However, some further epidemiological studies conducted on workers regularly exposed to creosote have confirmed some of the conclusions reached.

Creosote, a carcinogenic, mutagenic, and reprotoxic product that poses real dangers to human health.

Creosote is a skin, eye, and respiratory tract irritant.

This characteristic, regularly seen in workers frequently in contact with creosote, has led, according to the European CLP regulation, to classify creosote as H315 (causes skin irritation) and H319 (causes eye irritation).

Creosote can be a mutagen.

This toxicity has been demonstrated on animals in proportions that vary depending on the type of creosote, the concentration levels, and the factors related to the animals themselves. It is scientifically difficult to reach a conclusion on this issue, but there is a body of evidence that leads us to be very cautious on the subject.

Creosote is a carcinogen.

Animal studies have clearly shown an increase in skin cancer in proportions that are highly dependent on exposure. The "general public" literature reports a more extensive risk of cancers in various organs (lungs, prostate, pancreas, throat, etc.) without clear evidence.

According to the European CLP regulation, creosote is therefore classified as a class 1B carcinogen (H350 probable carcinogen). This classification is based on a 2A carcinogenic classification by the IARC (limited evidence in humans but sufficient evidence in animals) and on a 1B classification by the EPA (presumption of carcinogenicity in humans based on evidence in animals).

Creosote is a reproductive toxicant.

Some studies have shown that creosote may affect early intrauterine fetal development and cause increased fetal deaths. The assessment made on creosote in Europe in 2021 as part of the CLP regulation recommends a classification of H361d (may cause harm to the fetus) as a point of concern.

In addition, animal studies clearly show the impact of creosote on the offspring of the exposed generation with fertility problems and a significantly affected development of their own offspring.

This leads to the same assessment as before, consisting in recommending a classification of creosote as H360F (may affect fertility) which points, this time, to impacts deemed to be a hazard.

There are three ways to be exposed to creosote and its health impacts:

- by ingesting creosote: this risk is very limited. Intake via food involves concentrations too low to be considered dangerous.
- by breathing in volatile products contained in creosote: this risk exists during the production phases for workers close to the impregnation chambers for hot production of creosote-treated poles or, worse, close to the dipping or spraying areas for cold production.

- by contact with creosote: this risk exists at all phases of the life of the poles and concerns production agents as well as shippers, installers, and individuals responsible for recycling.

The assessment made by Europe in 2021 [1] concluded that:

- the exposure of installers and workers brushing creosote-treated wood after it has been cut is sufficient to cause concern about the health hazards mentioned above.
- the exposure of workers at impregnation plants is high and not acceptable without specific protective measures, especially since creosote has negative effects on the three components deemed the most dangerous and unacceptable: reprotoxicity, carcinogenicity, and mutagenicity.

Regulations tend to address public health issues in an increasingly urgent manner: the progressive banning of proven dangerous products such as creosote is a sign of this. This movement is developing, first and foremost, in the most developed countries.

2.2. Creosote, invasive pollutant, a hazard for the environment

Creosote is generally not very soluble in water but, because of its complex composition, it contains substances that are very soluble in water and others that are very volatile.

The polluting components of creosote are found in all biotic environments where life develops.

The impact of creosote on the environment comes mainly from the polluting power of the PAHs it contains.

In water, PAHs in creosote are, at best, rapidly photolyzed (broken down by light). Due to light attenuation in natural aquatic environments, the time required for photolysis of half the quantities (half-life[2]) of PAHs varies, depending on the PAHs, between one day and almost two years.

We find volatile PAHs **in the air**. While in the atmosphere, they are subjected to various degradation processes: mainly photolysis, secondarily reactions with the various oxidants present in the atmosphere in a gaseous state. Under these various influences, the half-life of PAHs in air varies between one and seven hours.

Rainfall can cause PAHs in the air to spread to water and land, leading to traces of them being found on plants and animals, and consequently in our food. Since these compounds are not very hydrophilic, they are also found in sediments. PAHs are therefore pollutants, some of which are persistent, that contaminate all environments.

[1] https://echa.europa.eu/documents/10162/fc41edcf-3732-2ba9-6a14-0fb9b423fd6c

[2] The half-life is the time at the end of which only half of the initial product remains, the other half having disappeared as a result of various decomposition and transformation mechanisms.

The air emissions of eight PAHs of particular concern are subject to special monitoring; four of them are used in making creosote. Despite special efforts, emissions of these products in France have stagnated since 2010, reflecting our dependence on them.

Creosote also poses hazards to soil, water, and air.

Soil pollution is predominantly widespread and comes from deposits of PAHs in the air. It can also result from point source pollution.

Several stages in the life cycle of creosote-treated poles pose a risk of environmental pollution:

- when applying the product to the wood.
- when handling treated wood, shipping it, installing it, and removing it by the various professionals in the chain of persons involved.
- when using treated wood, due to the diffusion of creosote in water, the air, or the soil.
- as waste, when the user of the treated wood must dispose of it.

Creosote, like most insecticides and fungicides, is particularly toxic to marine organisms.

The regulations tend to be more and more restrictive with regard to controlling and reducing the release of toxic components.

3. The creosote value chain

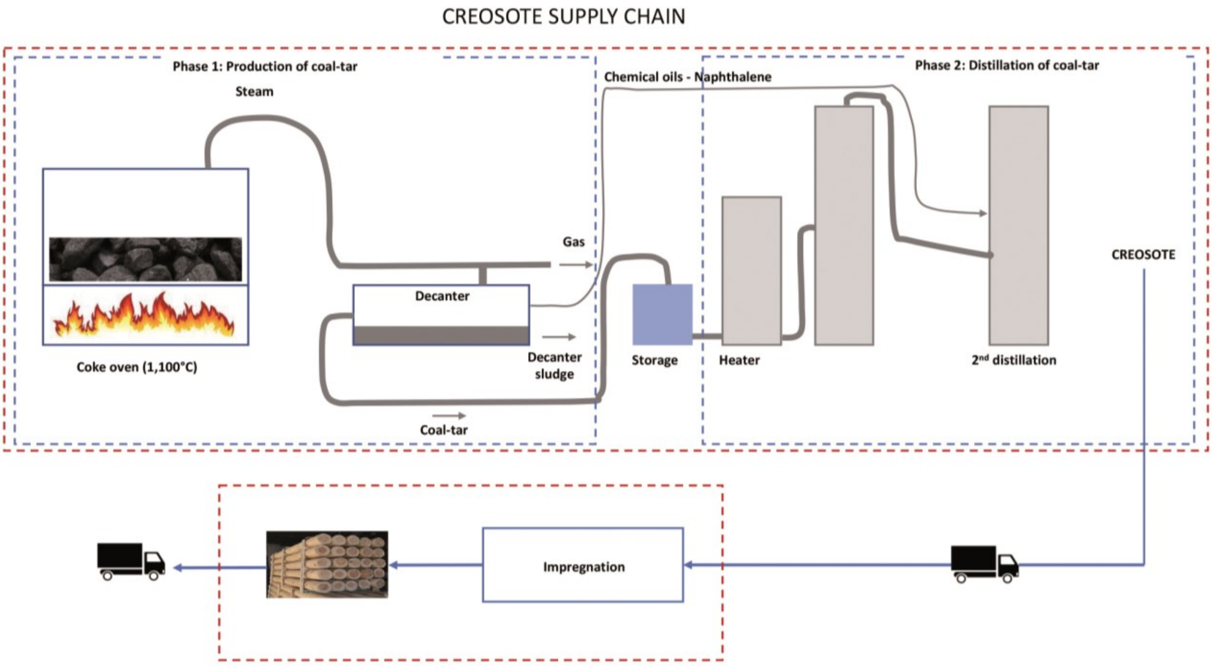
3.1. The production of creosote (from coal-tar)

Creosote is a by-product of the manufacture of steel from coal.

The manufacture of creosote involves two main steps (diagram 1). Some manufacturers take care of the whole manufacturing process, others only a part of it: coal-tar production for some, or coal-tar distillation for others.

The first step is the production of coal-tar. These tars are produced by decanting the vapors from coke ovens, which supply coke to steel mills.

Diagram 1. Complete creosote circuit, from production to product application



Source: Mach&Team, based on Nicholas P. Cheremisinoff, Paul Rosenfeld, Anton R. Davletshin (2008).

During this stage, the coking of coal produces many products with various uses, including:

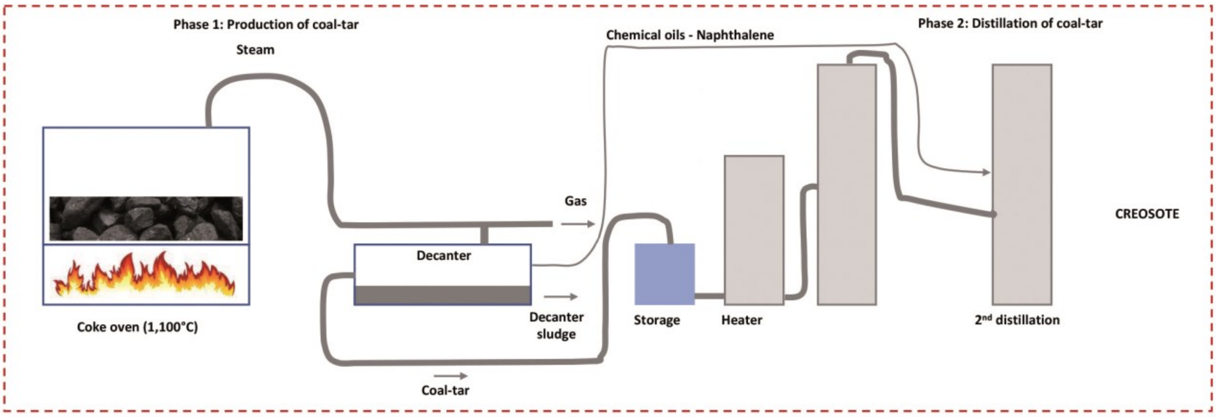
- coke, used in steel mills to reduce iron ore and obtain cast iron, the first step in steel manufacturing.
- coal pitch, used to manufacture anodes and cathodes but also as an insulating and sealing agent.
- naphthalene, a chemical substance used in the manufacture of plasticizers, dyes, and resins.
- coal-tar, which is used in shampoos, soaps, and anti-lice products.

Coal-tar is therefore generally produced in steel mills, i.e. in the leading steel-making countries, or in coal-producing countries for which they are responsible for part of the processing (the coke being delivered to steel mills that do not produce it directly). This production is quite capital-intensive and is increasingly subject to strict health and safety regulations; hence, it is rather concentrated.

The second step is the production of creosote by distillation of coal-tar (diagram 2). Depending on the case, one or more distillation steps are required. Creosote is only one of the by-products of this distillation process.

Creosote is therefore produced mainly in specialized refining facilities owned by chemical companies.

Diagram 2. Creosote manufacturing process



Source: Mach&Team, based on Nicholas P. Cheremisinoff, Paul Rosenfeld, Anton R. Davletshin (2008).

Creosote is then mixed with a solvent or oil and sent to raw pole impregnation plants located mainly in countries with a large forestry industry. These plants are either large (close to the wood production sites) and export a significant part of their production, or small (close to the consumption sites). Therefore, the industry is highly fragmented.

3.2. Wood impregnation processes with creosote

The treatment of wood is a key step that determines its service life. This treatment consists of impregnating the wood with a fungicidal and insecticidal substance, in this case creosote.

Historically, three main methods of impregnating wood have been used:

- dipping it in a preservative bath, a process that results in significant leaching rates.
- spraying the wood with preservative, which results in high leaching rates, a process that has now been virtually abandoned.
- pressure impregnation.

The impregnation method must be adapted to the porosity of the treated wood, to the degree of protection desired, and to the expected service life of the treated wood. The electric poles, for which a maximum life expectancy is expected, are therefore all pressure impregnated, regardless of the wood type used.

Pressure impregnation is done in sealed chambers in which the creosote and the wood undergo cycles of pressure variations designed to increase the quality of the impregnation. In Europe, three processes are primarily used (their American equivalents exist under other names), they include:

- the *Rüping* process which consists of placing the wood under a pressure of 4 bars for 15 minutes before injecting the creosote into the enclosure and increasing the pressure to 8 bars until the refusal (end of the impregnation process). The cycle ends with 30 minutes in a vacuum at 0.3 bar. This process is used for impregnable woods like pine.
- the *Bethell* process first subjects the wood to a vacuum at 0.2 bar for one hour before injecting the creosote into the cylinder and increasing the pressure to between 8 and 12 bar until refusal, then subjecting the treated wood again to a vacuum at 0.2 bar for 30 minutes. This process is also used for impregnable woods like pine.
- the *Estrade* process consists in drying the poles by subjecting them to hot air ventilation at 80-100°C for 48 hours, then impregnating them using the *Bethell* method (see above). This process is used for wood types that are moderately resistant or resistant to impregnation (fir and spruce).

Since creosote is not soluble in water, it is usually diluted for the impregnation phase in a petroleum-based solvent, which facilitates penetration of the product into the pile of spaced raw poles heated under pressure in the impregnation chamber.

Depending on the use and the conditions of use, it is therefore possible to use electricity poles made of softer, less dense, more easily impregnated wood (requiring about 92 kg of creosote per m^3 of wood), or poles made of harder wood, whose impregnation will consume more energy but less creosote (about 70 kg/m^3 of wood).

During the impregnation process, the wood absorbs a quantity of treatment product, depending on its own properties and the type of treatment desired. Subsequently, the quantity or retention rate is frequently used to indicate the amount of product absorbed and retained by the wood.

4. Measures taken, or to be taken, during the various phases of the life cycle of utility poles to address the hazards of creosote

The hazards of creosote to the environment and human health have led to measures, mainly regulatory, limiting the risks of creosote use at each stage of the creosote-treated pole life cycle. Europe, and particularly France, are pioneering areas in this field. The measures taken and deployed there represent the most advanced solutions for dealing with the dangers of creosote and creosote-treated poles.

As a result, France has the most restrictive regulations regarding creosote.

Outside Europe, all types of scenarios exist: a less advanced consideration of the dangers of creosote leading to less protective solutions for human health and for the environment, or the virtual absence of appropriate solutions. This lack of solutions is also found in countries that have conducted studies on the impact of using creosote-treated poles on their soils, with very clear results.

4.1. Measures for the production phase

During the production of creosote treated poles, creosote has various ways of impacting the environment and the health of workers.

Creosote's properties, as described above, make two types of precautionary measures necessary when impregnating creosote-treated poles:

- measures to protect the environment from possible leakage of toxic creosote components.
- measures to protect the workers working at the impregnation plants.

4.1.1. In countries with the most extensive regulations

Wood impregnation plants with creosote are classified facilities subject to authorization. More recently, in Europe, the regulatory authorities also wanted to include these facilities as part of the European Industrial Emissions Directive (IED) to improve the control of emissions.

With respect to environmental protection, the main constraints imposed on wood impregnation plants using creosote are:

- sealed impregnation chambers to prevent volatile components (mainly PAHs) from being released into the air.
- recovery systems for volatile components.
- oxidation systems for these components to destroy them (usually by heating them to temperatures exceeding 900°C for one to two seconds).
- biological water treatment plants used for operating and cleaning the impregnation plants.

The mandatory and recommended measures for workers include:

- wearing gloves thick enough to prevent skin contact when handling poles.
- wearing a face shield or goggles to prevent eye irritation.
- wearing a mask to prevent lung irritation.
- wearing safety shoes.

These measures apply to all workers, especially those involved in cleaning and maintaining the impregnation chambers, but also to those who work in the control and analysis laboratories linked to the production facilities.

4.1.2. In countries with less extensive regulations

More lenient regulations are generally recommended to protect people in close contact with creosote, primarily workers. These provisions are rarely, if ever, mandatory and are not enforced.

The workers are therefore very exposed to the above-mentioned dangers.

As for the environment, it may often not be subject to any particular protection measures against creosote and its most dangerous components.

4.2. Measures concerning the storage phase

The storage phase poses a greater risk to the environment than to the workers at the sorting and storage facilities for creosote-treated poles. Indeed, workers have less direct, less prolonged and more isolated contacts. In the case of end-of-life storage, the creosote-treated poles are older: the volatile hazardous components of creosote have then almost disappeared.

4.2.1. In countries with the most extensive regulations

The transit, sorting, and storage sites for creosote-treated poles are deemed to be storage sites for hazardous materials.

Constraints are therefore imposed to minimize contamination of the environment:

- reinforced protection against fire at the facilities and, more particularly, at the storage buildings.
- reduced exposure to rain to prevent runoff from washing hazardous products off the stored poles.
- storage areas that avoid soil contamination: storage bins (to avoid contamination between products) with concrete floors.
- treatment facilities for runoff water that may have been in contact with the poles (i.e., that may have also runoff from pole handling, loading and unloading areas).
- increased monitoring of waste and discharges.

Rail and power grid managers, who are the main parties involved, are often exempted from such measures by the regulations: this amounts to leaving them liable for their impact on the environment.

4.2.2. In countries with less extensive regulations

The storage of creosote-impregnated wood is not subject to any particular attention.

4.3. Measures concerning the operational phase

Although the creosote-impregnated poles are installed directly in the ground and are therefore in contact with it, no study has been able to show a significant risk to the soil or to the groundwater.

There are no specific provisions for managing the use of creosote-treated poles during their operational phase.

4.4. Measures concerning end-of-life management

4.4.1. In countries with the most extensive regulations

The French Environment and Energy Management Agency (ADEME) classifies wood waste into three categories with respect to recycling requirements (diagram 3).

Diagram 3. The three types of wood waste according to ADEME

Wood waste type A = Pure biomass	Wood waste type B = Non-hazardous waste	Wood waste type C = Hazardous waste
Contains chemical contaminants at **natural** concentrations	Contains chemical contaminants at **non-hazardous** concentrations	Contains chemical contaminants at **hazardous** concentrations

Type C wood wastes include those treated with hazardous materials, including creosote. They can neither be recycled nor recovered.

This type C wood waste must be traceable and treated in regulated, classified facilities reserved for hazardous waste.

Unlike most other wood treatment products, the combustion of creosote does not emit heavy metals. Its energy recovery is therefore a preferable solution.

Creosote-treated wood must be incinerated in approved facilities that have the following features:

- the grinding may be done by a third party but must be done with a dust collection system.
- incineration is done by pyrolysis at 700°C without oxygen after drying at 200°C in ovens that comply with regulatory requirements.
- these ovens must be able to reach 1,100°C for two seconds with purification of the fumes, if the acceptability thresholds for hazardous substances are exceeded.
- the heat produced by the pyrolysis process is collected to heat steam for generating electricity.

Type C wood waste can also be incinerated in cement kilns, making the recycling of creosoted poles more accessible in some emerging countries.

4.4.2. In countries with less extensive regulations

Creosote-treated wood is not subject to any special consideration and is generally disposed of in normal landfills without special precautions.

Even in the United States, in most states, despite creosote being classified in the same way as it is in Europe, creosote-treated poles are not deemed to be hazardous waste and can therefore be disposed of at municipal landfills: however, some refuse them.

In general, risks to human health are considered before risks to the environment. Ausgrid's (Australia) pole installation guide, for example, states: "*Burning CCA-treated power poles emits toxic fumes laden with arsenic and chromium. If you are not required to be on site, keep your distance and be careful of any wind*".

5. Creosote regulations

5.1. Several agencies recognize the hazardous nature of creosote

The classifications of creosote as a hazardous material are converging towards consistent, homogeneous conclusions.

The European Chemicals Agency (ECHA) classifies creosote as:

- skin irritant level 2 (H315): **human experience or data showing reversible skin damage following exposure for up to 4 hours.**
- skin sensitizer level 1B (H317): **may cause skin allergy.**
- eye irritant 2 (H319): **causes severe eye irritation.**
- carcinogen 1B (H350): **may cause cancer.**
- reprotoxic 1B (H360): **may impair fertility or harm the fetus.** Acute aquatic toxicity (H400): **very toxic to aquatic organisms.**
- chronically toxic to the aquatic environment (H410): **very toxic to aquatic organisms, causes long-term adverse effects.**

IARC classifies creosote as a type 2A carcinogen: **probably carcinogenic to humans (limited evidence of carcinogenicity in humans and sufficient evidence in animals).**

The EPA classifies creosote as a type 1B carcinogen: **probably carcinogenic to humans.**

5.2. In Europe

European regulations directly or indirectly concerning creosote have been developed for several years along the following lines:

5.2.1. Recognition of creosote as a hazardous product

Creosote is an active substance meeting the criteria of European Regulation (EC) no. 1272/2008 for classification as a category 1B carcinogen with no threshold value, reprotoxic 1B (may impair fertility and harm the fetus), reprotoxic 2 (likely to impair fertility or harm the fetus), and acute toxicity to category 1 aquatic organisms.

5.2.2. Progressive restriction to ban on creosote use

Regulations affecting the production, sale, and use of creosote come from two initiatives:

- the regulation concerning biocidal products.
- and, more generally, the regulation of chemical substances.

In 1998, European Directive no. 98/8/EC concerning the placing of biocidal products on the market introduced the need for any biocidal product to have a marketing authorization and established the procedure for granting and managing those authorizations. In this regard, creosote is listed in Appendix 1 as one of these products.

European Regulation no. 552/2009/EC - concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) - specifically identifies creosote and prohibits its sale and use in Europe, but grants an exemption:

- for creosote with low phenol and benzo[a]pyrene content: the creosote *historically* used, known as type A creosote - comprising up to 85% PAHs, 60% of which are volatile carcinogenic compounds such as naphthalene, anthracene, and benzo [a]pyrene - is now banned.

  The type B and C creosotes now in use have a lower volatile content with respective maximums of 20 and 10%. These type B and C creosotes are obtained by raising the distillation temperature of the creosote during its manufacturing process.

- for professional applications.

This is the first step towards a possible ban on creosote.

The EU Biocidal Products Regulation no. 528/2012/EU, which replaces Directive no. 98/8/EC, takes another step along the path of hazardous products by banning:

- products recognized as carcinogenic, mutagenic, or reprotoxic.
- endocrine disruptors.
- persistent organic pollutants (POPs).

In addition, this regulation also lists the conditions for exceptional exemptions from these bans.

This last regulation is thus a further step towards a possible ban on creosote.

The regulation grants the approval of creosote (active substance) in Europe for a maximum period of five years, which expires on April 30, 2018.

Implementing Decision no. 2017/2334/EU acts as an extension of the approval of creosote in Europe, i.e. until October 31, 2020.

By implementing Decision no. 2019/961/EU, the European Commission authorizes a provisional measure taken by France to ban the use of creosote.

Implementing Decision no. 2020/1038/EU acts as an extension of the approval of creosote in Europe until October 31, 2021.

Implementing Decision no. 2021/1839/EU is a further extension of the approval of creosote in Europe until October 31, 2022. These postponements, certainly dictated by influential people, are granted to have time to document through studies a point of exemption allowed by the

2012 regulation: indeed, an exemption from the ban of a biocidal product can be granted if the risk to humans and the environment from exposure to the active substance under realistic worst-case conditions is shown to be negligible.

In this context of successive postponements of the creosote ban, in February 2022 France submitted a proposal to extend the creosote ban to Europe, trying to leverage an early French regulation (see paragraph 8.3 below). Evaluation of this proposal by the Risk Assessment Committee (RAC) and the Socio-Economic Analysis Committee (SEAC) began in April 2022.

5.2.3. Establishing an environmental protection framework for creosote products

European regulations also include topical, generic texts, not specifically mentioning creosote, intended to build a more environmentally protective Europe. While these texts do not target creosote, products containing creosote and facilities using creosote must comply with these texts. These include:

- the directive concerning drinking water.
- the directive concerning groundwater.
- the directive concerning the treatment of waste.
- the directive on landfills.

5.3. In France

In Europe and in the world, France stands out as a pioneer country in regulating creosote, both in terms of the production, use, and treatment of creosote-treated poles and in terms of the ban on selling creosote treated products.

French regulations concerning creosote have been developed for several years along the following lines:

5.3.1. Recognition of creosote as a hazardous product

On this point, France adopts the European regulations and uses the same international classifications.

5.3.2. Progressive restriction to ban on creosote use in France

France followed the European regulation until 2018 and then took the lead by banning creosote for all types of use in France with the Decree dated December 18, 2018. This text prohibits any action of placing new and used products on the market, including by importers.

However, this Decree does not prohibit the production of creosote-treated wood in France to be exported.

5.3.3. Inspection and adaptation of facilities producing and treating creosote-treated poles

French regulations have progressively refined the conditions for production units (classified as ICPE 2415), storage facilities, or recycling facilities for creosote-treated poles (classified as ICPE 2718).

As far as treated wood production facilities are concerned, the Decree dated December 17, 2004 specifically defines the desired properties to guarantee safety and environmental protection. These provisions were further strengthened by the Order dated September 8, 2008 (water treatment, emissions recovery, waste treatment, etc.) and enhanced by a list of the best available techniques in the Order dated June 28, 2021.

The storage of treated wood and, more generally, of hazardous products was regulated by the Order dated December 30, 2002, amended by the Order dated October 10, 2012. The main points addressed were mentioned in section 7.2 (see above).

The transit and sorting of creosote-treated wood is covered by the provisions of the Order dated June 6, 2018.

Finally, the incineration of treated wood must be done at facilities that comply with the specifications stated in the Decree dated September 20, 2002 on the co-incineration of hazardous waste, as amended by the decrees dated August 3, 2010, October 3, 2012, and December 18, 2012.

5.4. In the U.S.

In 2008, the EPA decided that products containing arsenic, creosote, or pentachlorophenol could continue to be used as long as the safeguards recommended in the Reregistration Eligibility Decision (RED) documents were followed. These measures include ventilation of impregnation areas and locked doors on wood treatment cylinders.

In 2019, the EPA conducted a risk analysis on these same products as part of their reauthorization. For each of these, the EPA highlighted that the measures recommended by the RED documents did reduce worker exposure, but continued to pose a health risk to workers at the impregnation plants. Creosote and arsenic derivatives have also been shown to pose environmental risks.

In 2021, the EPA issued proposed transitional decisions for products containing arsenic, creosote, or pentachlorophenol. The EPA determined that the risks associated with the use of pentachlorophenol outweighed its benefits and therefore proposed it be banned. For creosote and chromate arsenic derivatives, the EPA proposed additional mitigation measures to protect the health of workers at wood treatment facilities.

In April 2022, the EPA banned pentachlorophenol which had been discontinued in Europe since the early 2000s.

When it comes to creosote, there are no regulations other than recommendations for protective actions with respect to the product: reuse of creosote products is unrestricted; dumping of creosote products at public landfills is left to the discretion of each state (many states allow it).

5.5. In South Africa

South Africa has a significant wood processing industry which supplies southern African countries (Namibia, Zimbabwe, Botswana, Mozambique, and Zambia) and some eastern African countries (Kenya).

The country has established an approval procedure for wood treatment products and impregnation plants which allows it to monitor wood treatment activities. However, these procedures did not result in any significant ban: creosote is still widely used in the country.

The SAWPA (professional organization of the wood treatment industry) has issued recommendations for recycling creosote-treated wood: do not burn it, incinerate these products at specialized plants, limit landfill disposal to small quantities, and wash your hands after any manual handling. But there is no evidence that these recommendations are widely followed.

6. Funding for projects containing creosote

6.1. At the World Bank [3]

Environmental and Social Standard no. 3 (ESS 3 – Resource Efficiency and Pollution Prevention and Management) applies to all elements of a World Bank funded project. This standard prohibits the use of certain chemical pesticides.

In the articles on pesticide use, ESS 3 applies a precautionary principle by deeming a prohibited active ingredient to be a prohibition on the substance (“*In addition, the Borrower will also not use any pesticide products that contain active ingredients that are restricted under applicable international conventions or their protocols or that are listed in, or meeting, the criteria of their annexes*”).

ESS 3 also considers cancer, genetic mutation, and reprotoxicity risks as tier 1 risks requiring a pesticide ban: “*The Borrower will also not use any formulated pesticide products that meet the criteria of carcinogenicity, mutagenicity, or reproductive toxicity as set forth by relevant international agencies*.”

For other products posing a serious health and environmental hazard, ESS 3:

- defers to national regulations.
- prohibits the use of the substances by non-professionals and where there are no measures to protect people and "proper" facilities to manage, store and use these products.

Without specifically mentioning creosote, the World Bank **prohibits** funding for projects that include creosote products because creosote is a known carcinogen.

[3] https://thedocs.worldbank.org/en/doc/936531525368193913-0290022018/original/EnvironmentalSocialFrameworkFrench.pdf#page=53&zoom=80

6.2. At the European Investment Bank (EIB) [4]

At the EIB, all projects must comply with current internal regulations. Standard 1, Section 5 states that:

- "*All projects located in the EU and EFTA*[5]*, Candidate and potential Candidate countries shall comply with the applicable national and EU legislation. All projects located in the rest of the world shall comply with the applicable national legislation and with the core principles and essential procedural elements laid down by the EU legislation that the EIB considers relevant to the assessment and management of environmental, climate and/or social impacts and risks.*"
- "*The promoter shall seek to avoid, reduce or eliminate the use and storage of hazardous substances and materials of high concern and consider replacing them by less hazardous substitutes, where suitable economically and technically viable alternatives are available. Furthermore, the promoter is also encouraged to develop projects that lead to the innovative development and use of sustainable substitutes.*"
- "*Where avoidance or substitution is not feasible, the promoter shall consider the safety use and storage of hazardous substances and materials by strictly applying/aligning to the requirements of EU horizontal chemicals legislation and international good practices.*"

This obligation of means is therefore not very binding insofar as the promoter's efforts can neither be quantified nor evaluated.

The EIB does not impose any specific restrictions on creosote, but encourages the promoter of the bank-funded project to find a possible alternative.

6.3. At Kreditanstalt für Wiederaufbau (KfW) [6]

KfW published an exclusion list that targets certain insecticides. According to this list, the following are excluded:

"*Production or trade in any product or activity subject to national or international phase-out or prohibition regulations or to an international ban, for example:*

- *certain pharmaceuticals, pesticides, herbicides, and other toxic substances (under the Rotterdam Convention, Stockholm Convention and WHO "Pharmaceuticals: Restrictions in Use and Availability").*
- *ozone depleting substances (under the Montreal Protocol).*
- *prohibited transboundary trade in waste (under the Basel Convention).*"

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[4] https://www.eib.org/attachments/publications/eib_environmental_and_social_standards_fr.pdf

[5] The current EFTA member states are Iceland, Liechtenstein, Norway, and Switzerland.

[6] https://www.kfw.de/PDF/Download-Center/Konzernthemen/Nachhaltigkeit/Ausschlussliste_EN.pdf

According to this list of exclusions:

- pentachlorophenol, listed in Appendix I of the Stockholm Convention[7], is excluded.
- creosote is listed as a substance meeting the criteria of Appendix I of the Rotterdam Convention[8], following a notification from Latvia, regarding the restriction of creosote to industrial uses.

KfW does not impose any particular restrictions on creosote because this substance, which is under investigation by the Convention, is not (yet) listed in Appendix III of the Convention.

[7] http://chm.pops.int/Implementation/Alternatives/AlternativestoPOPs/ChemicalslistedinAnnexA/tabid/5837/Default.aspx

[8] http://www.pic.int/Implementation/FinalRegulatoryActions/FRAEvaluationToolkit/NotificationsthatSatisfyAnnexI/ListofAnnexInotifications/tabid/5570/language/en-US/Default.aspx

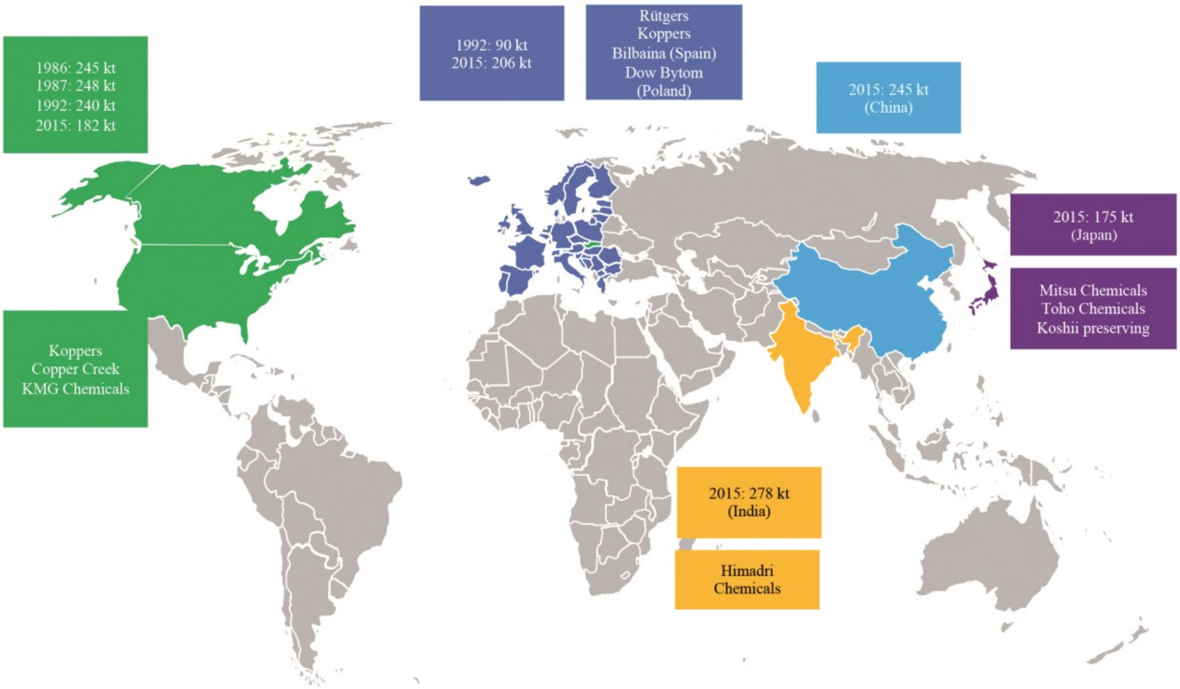
7. Current status of creosote use

7.1. Creosote production

World coal-tar production has stabilized at around 12 million tons.

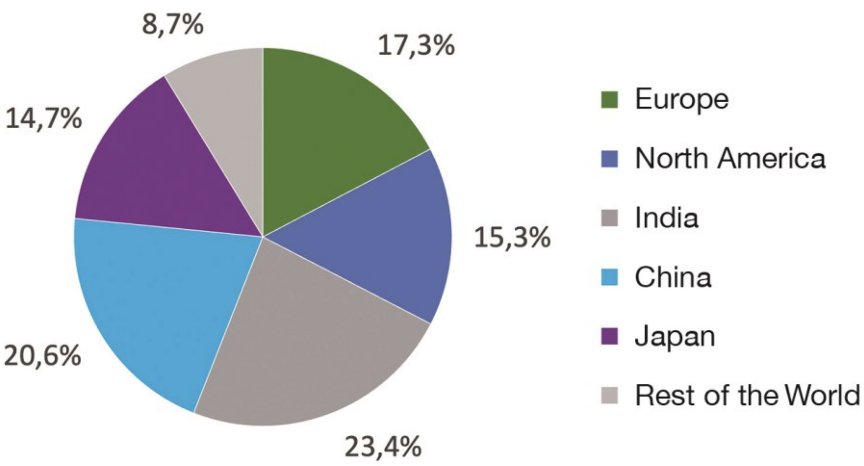
Map 1 shows some historical production levels and the main producers in each major continental area.

Map 1. Main creosote producing areas



Source: Mach&Team from xcellentinsights.com

Graph 1. Market shares of major creosote producing areas in 2015



Source: Mach&Team from xcellentinsights.com

The main creosote manufacturers are among the leading biocide manufacturers.

The global biocides market in 2018 was split 53% in the Americas, 24% in Asia-Pacific (APAC), and 23% in Europe.

It was dominated by two American industry heavyweights: Koppers (19%) and Lonza (15%), followed by Rütgers (4%), Troy, Huntsman Viance, KMG Chemicals (mainly with creosote where its position is very strong) and Dow Bytom.

Note that the three world leaders are, in the same order, the three leaders of the major continental markets (American, European and Asian).

The wood impregnation industry therefore buys from these global suppliers, often through their sales offices located around the world.

More specifically, in Europe, creosote production was distributed as follows in 2016:

Table 1. European creosote production in 2016

Producer	Location	Creosote (tons)
Creosote for Europe		
Koppers	United Kingdom, Danemark, The Netherlands	25,000
Rütgers	Germany, Poland, Belgium	30,000
Bilbaina	Spain	10,000
Dow Bytom	Poland	4,000
Others		11,000
Creosote for export		
Exports		40,000

Source: based on data from SEA Full Report, WEI-IEO (Brussels), August 2016.

7.2. Production of creosote treated poles

Creosote treated poles are produced in a much more dispersed manner. Nevertheless, four types of producing and exporting countries can be identified.

In 2020, most of the major Western countries were exporters as shown in Map 2: the United States (12.5% of world treated wood exports), Canada (9.2%), France (3.8%), and Germany (3.5%). Canada and the United States are among the major consumers (they are the largest producers of treated wood), while France has only an industry dedicated to exports.

Some wood-producing countries are among the major exporters. Wood is processed close to the logging sites: Lithuania (8.2%), Czech Republic (4.9%), Sweden (4.9%), and Latvia (2.5%).

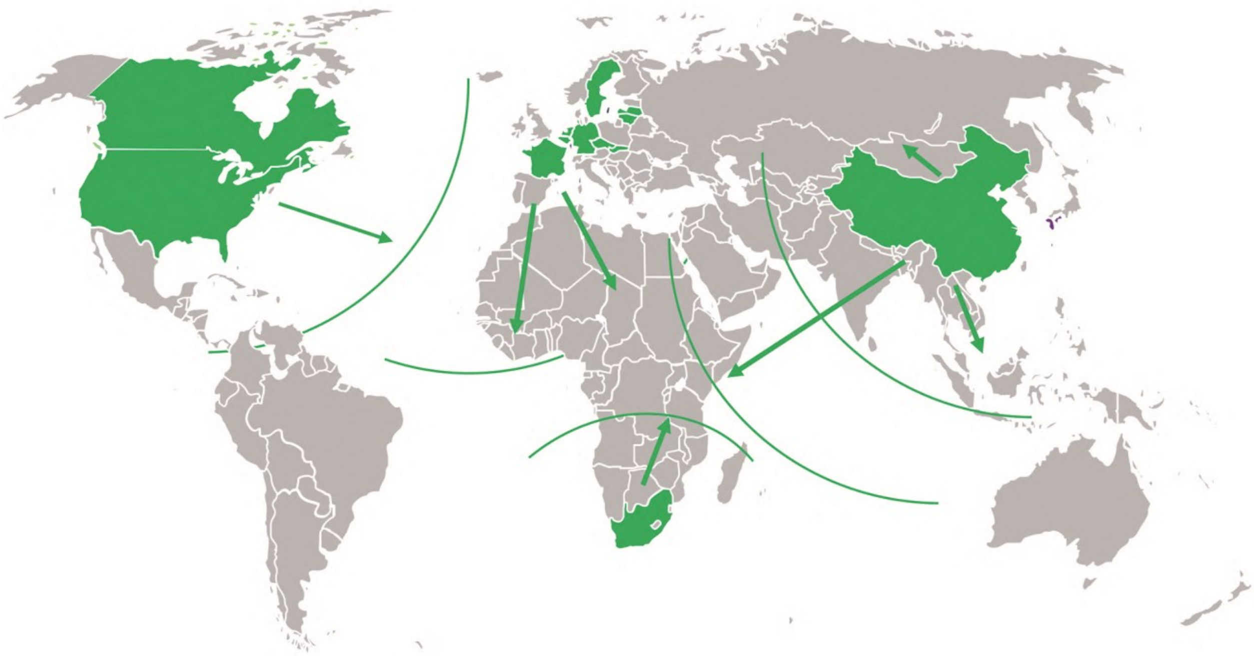
Countries with historical trade links with emerging countries are also among the main exporters of treated wood: Belgium (6.9%) and the Netherlands (6.1%).

Countries with a regional influence, such as South Africa (5.8%), which produces a substantial amount and exports a significant quantities to Southern Africa. To a lesser degree, Uganda and Tanzania export their production to neighboring countries.

Apart from South Africa, all major exporting countries are home to processed wood producers with strong links to Latin American, African, and certain Asian countries.

However, a very fragmented wood impregnation industry exists in most countries, especially when it comes to creosote.

Map 2. Main exporting countries of creosote treated wood and poles



Source: Mach&Team.

North American production is mainly intended for North America. The small percentage of exports goes to various countries (Europe, Africa, and Southeast Asia).

European production is mainly exported to West Africa and the Middle East.

Chinese production is primarily exported to areas of influence close to China (Mongolia and South-East Asia) but also reaches more distant areas of influence (East Africa).

South African production supplies the entire Southern and Eastern Africa region.

7.3. Power pole market

Worldwide, wood poles dominate the electric utility poles market, accounting for over 80% of the market. Concrete poles are on the rise in many countries, but in most cases are not the preferred solution. Steel poles and, even more so, composite poles (due to their price) occupy niche markets.

Table 2. Utility pole market - technology shares

Pole type	Area/ Country	Wood	Steel	Concrete	Composite	Total	Installed base
Electrical							
	North America	90%	7%	2%	1%		
	Australia	80%	1,9%	7,5%	10,6%		6.3 million (2004)
	New Zealand	38%	3%	58%	1%		1.3 million (2008)
	France	33%		67%			15 million
Telephone							
Street lighting							
Total					**<1% 228 M USD (2018)**		**1.6 billion**

Various sources analyzed and summarized by Mach&Team.

7.4. Examples of local wood utility pole markets

Table 3. Some examples of national market structures

Country	Production	Number of plants	Market	Installed base	Main manufacturers
United States			1.5 M – 2 M	130 M – 160 M	1. Stella Jones 2. Koppers
South Africa	350 k		126 k (2001)		Thesens, Wood Line, Boland Wood
Sweden		2	14 k		Scanpole, Rundvirke
Belgium		2			CCB, CIBB
Ireland		1	35 k (Cr)	2 M (Cr)	PDM Saint-Gobain
Germany		3			Peter Müller, Hiram, Fürstenberg
France		9			Bois imprégnés, France
Finland		3	100 k	10 M	Versowood, Pinar, Livari Mononen
Greece		3	90 k (Cr[9])	4.5 M (Cr)	
Cyprus			20 k (Cr)	240 k (Cr)	
Norway		2	30 k (Cr)	3,5 M (Cr)	Scanpole

Various sources analyzed and summarized by Mach&Team.

A study[10] conducted on power grids covering the period 1980-2017 showed that the length of the lines of a power grid in a country can be approximated with very good accuracy using the following formula:

- Number of kilometers (km) of lines = 0.03535 x number of households served + 1,459.19 x volume of electricity supplied (in TWh)

The result of this calculation is shown for all major countries in Appendix (Estimating the number of power poles in each country).

[9] Number of creosote treated wood poles.

[10] https://www.sciencedirect.com/science/article/pii/S2352340921006351

7.5. Lobbying and professional associations

In the major treated wood pole consumer and manufacturing countries, professional associations have been created to bring together the major players in the treated wood industry.

Some of these associations are involved in extensive lobbying and advocacy for a profession threatened by regulatory changes tending to exclude most treatment products or, at a minimum, to reduce their scope of use.

The most active are:

- in the United States, AWPA (American Wood Protection Association) (https://awpa.com).
- in South Africa, SAWPA (South African Wood Preservers Association) (https://sawpa.co.za).
- in Australia, TPAA (Timber Preservers Association of Australia) (https://www.tpaa.com.au/about/).
- in Europe, WEI-IEO (https://www.wei-ieo.eu/) represents the pressure treated wood industry in Europe and, more specifically, before the European Commission.

Other examples include:

- in the Scandinavian countries, NWPC (Nordic Wood Preservation Council) (https://www.nwpc.eu).
- in Japan, JWPA (Japan Wood Protection Association) (http://www.mokuzaihozon.org/english/).
- in the United Kingdom, WPA (Wood Protection Association) (https://www.thewpa.org.uk).
- in North America and Mexico, WWPI (Western Wood Preservers Institute) (https://preservedwood.org).
- in North America, SPTA (Southern Pressure Treaters' Association).
- in Canada, WPC (Wood Preservation Canada) (https://woodpreservation.ca/en/).

In addition to their lobbying activities, these associations have several additional missions, depending on the case:

- more or less objective information on wood treatment technologies, methods and products (all).
- establishing and managing a quality assurance and testing program (TPAA).
- quality label management (WPA, NWPC).
- developing and managing standards (AWPA, WPC).
- approving wood treatment substances (JWPA).
- research work (JWPA).

8. Alternatives to creosote

There are several alternatives to creosote-treated poles: wood poles treated with products other than creosote, steel poles, concrete, or composite materials.

At the same time, complementary solutions, such as lining the base of poles, make it possible to reduce certain disadvantages of treated wood.

Wood treatment solutions with non-creosote products have a much lower cost/effectiveness ratio than other solutions. On the other hand, no wood treatment product is harmless in terms of its impact on health and the environment because it contains potentially dangerous fungicides or insecticides.

The choice of an alternative is therefore based on:

- either the economic aspect, and it is important to approve the precautionary measures associated with this choice.
- or the level of toxicity and ecotoxicity, and it is important to choose the penalties that have the least impact on the environment.

8.1. Alternative wood treatments

Provided they are effective at protecting the wood, these alternative treatments have the advantage (as a replacement for creosote) of not significantly changing the design of the poles, the manufacturing process, or the installation methods.

The design and dimensioning of these poles remain identical because, when applied on the same wood species, these treatments do not modify the physical performance.

As far as the manufacturing of the poles is concerned, almost all alternative treatments are applied by pressure impregnation just like creosote. This makes it easy for manufacturers to adapt to these new products.

Finally, these poles are installed in the same way as creosote-treated poles: their size and weight are identical.

Wood impregnation products are often compounds made with metals with fungicidal and insecticidal properties: arsenic, copper, boron (in the form of borate or boric acid), and chromium.

All of these metals are hazardous, but because they are sometimes diluted in wood treatment products and combined with other substances, it is not possible to conclude that their individual properties are present in the final compound. Only studies specifically designed for each impregnation product can determine with certainty the danger for humans and the environment.

Arsenic is recognized as a carcinogen by the EPA (carcinogen A), by the ECHA (carcinogen 1), and by the IARC (carcinogen 1).

Chromium VI is recognized as carcinogenic by the IARC (carcinogen 1).

Therefore, the fact that a substance is not classified as a hazardous material may reflect the fact that the substance is not very harmful or that there is a lack of in-depth studies. This is why this report uses the classifications of the European Agency for the Control of Chemicals (ECHA) as of June 2022. It is quite plausible that further research will be conducted on certain substances and will lead to less favorable classifications.

In spite of these precautions in interpretation, often emphasized by scientists, many countries prohibit the presence of certain metals or chemical compounds in wood impregnation products. For example, the United Kingdom has banned the presence of chromium and arsenic since 2006.

Among the wood impregnating products used for utility poles, the following are the best known and most commonly used.

Important note: The three most common pole treatment solutions (creosote, pentachlorophenol, and CCA) are all based on highly toxic products. Only CCA is still allowed.

<u>Historical products</u>

8.1.1. Pentachlorophenol

Reference

Pentachlorophenol	**ECHA**	201-778-6	**CAS**	87-86-5 131-52-2 (Salt)

Description

Pentachlorophenol is an artificially produced substance that has been used since the 1930s as a pressure-impregnated oil for treating wood. It has been used extensively and the majority of treated wood utility poles installed in the United States today are treated with pentachlorophenol.

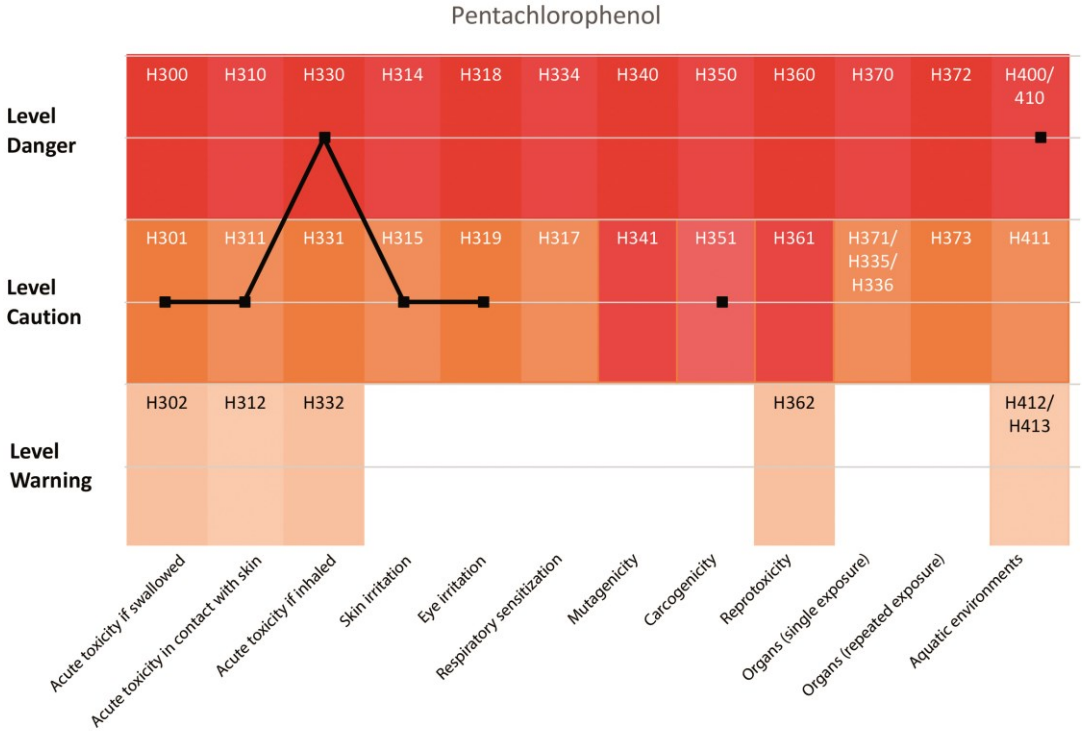
Pentachlorophenol is a chlorinated phenolic compound that can release dioxins when burned. However, it does not contain heavy metals or PAHs.

Toxicity and ecotoxicity

It is a relatively persistent irritant (H315, H319) and a strong endocrine disruptor.

Since the late 1960s, pentachlorophenol has been recognized and labeled in Europe as a very hazardous substance for humans and the environment.

Diagram 4. Toxicity profile of pentachlorophenol



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022)[11].

Regulations

Its use in consumer products was banned in Europe in 1992. It was completely banned by Denmark in 1996 and listed in 2015 in Appendix A of the Stockholm Convention on Persistent Organic Pollutants, i.e. banned for production, use, and import. Pentachlorophenol has also been banned since 1980 in Indonesia, since 1991 in India (which has continued to produce its salt for its own needs), as well as in New Zealand, Morocco, Ecuador and Sri Lanka, and its use has been restricted to wood treatment since 1982 in China.

Consumer countries

At the same time, pentachlorophenol has long been the leading treatment in the United States where it was banned for residential use in 1987. After being subject to precautionary measures recom-mended by the EPA, it was definitively banned in 2022.

Production

Pentachlorophenol has not been produced in Europe since 1992, when Rhône-Poulenc ceased its activities in this field. The last American producer, Cabot Microelectronics Cor-poration, a subsidiary of KMG Chemicals, was the world's largest producer until recently, but it ceased production at the end of 2021. However, it is still produced in other countries such as by Sigma-Aldrich, a Merck subsidiary, which still sells it, especially in China.

[11] ECHA shall not be liable for any consequences resulting from the use of ECHA data mentioned in this report.

Pentachlorophenol cannot be an alternative to creosote for treating utility poles. It is too toxic and already banned in many countries.

Acceptability summary [12]

Pentachlorophenol	
Summary in favor of ban	
Banned by WB NES 3	YES
Banned in Europe	YES
Banned in the US	YES
Risk of cancer, mutation, reprotoxicity	YES, H351
National exclusions	Europe, USA
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

8.1.2. Chrome copper arsenate (CCA)

Reference

Chrome copper arsenate	**ECHA**	Not listed	**CAS**	37337-13-6
Components				
Arsenic trioxide (As_2O_3)	**ECHA**	215.481.4	**CAS**	1327-53-3
Arsenic pentoxide (As_2O_5)	**ECHA**	215.116.9	**CAS**	1303-28-2
Lead hydrogen arsenate	**ECHA**	232.064.2	**CAS**	7784-40-9
Triethyl arsenate	**ECHA**	427.700.2	**CAS**	15606-95-8

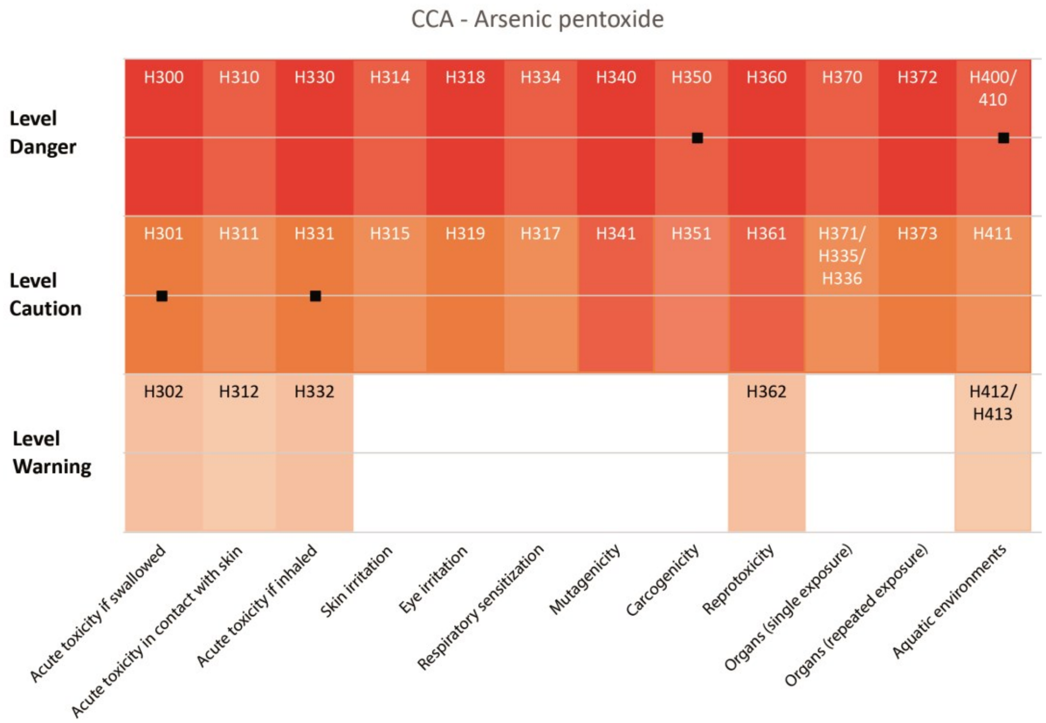
Description

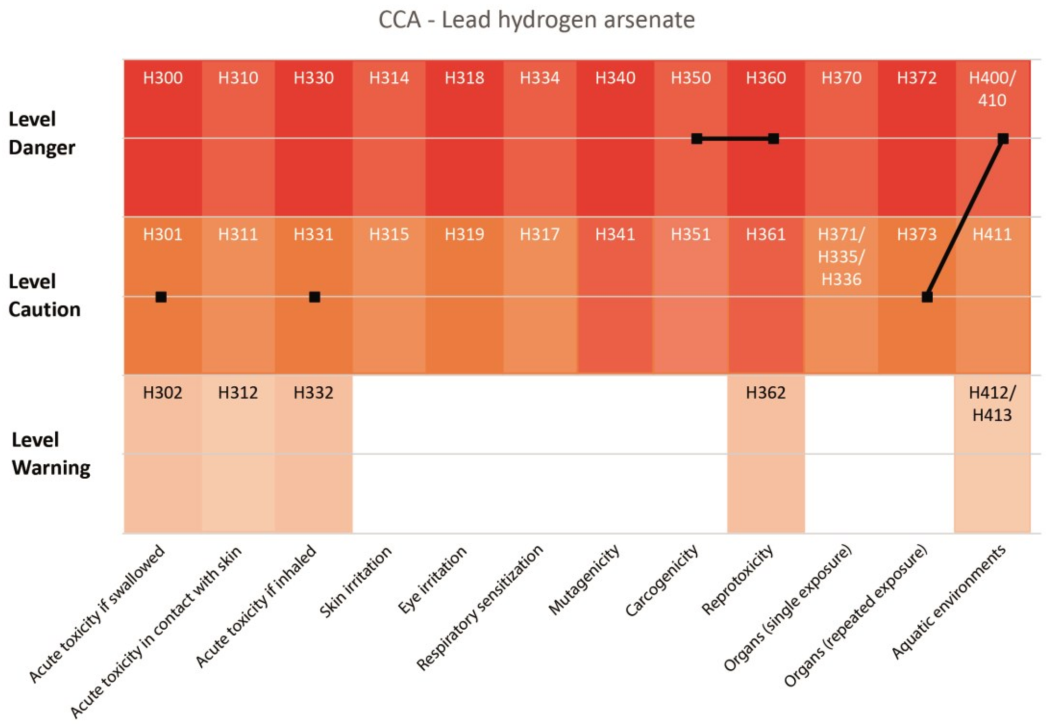
CCA is also a widely used treatment in many countries. CCA is an aqueous combination of copper (23-27% for its fungicidal properties), arsenic[13] (30-37% for its insecticidal properties) and chromium (38-45%, used to bind products in wood and as a protector against ultraviolet rays).

[12] The acceptability summaries proposed in this report are not expert opinions but a compilation of the data available in July 2022. The CMR risks (see glossary) are in accordance with ECHA publications. A ban in Europe or the United States, as well as a CMR classification, results in a negative acceptability opinion. The absence of such criteria but a classification as hazardous results in a "yes but" acceptability opinion, requiring the implementation of specific protective measures when using the substance.

[13] CAS No.: 7440-38-2 – ECHA No.: 231-148 - 6.

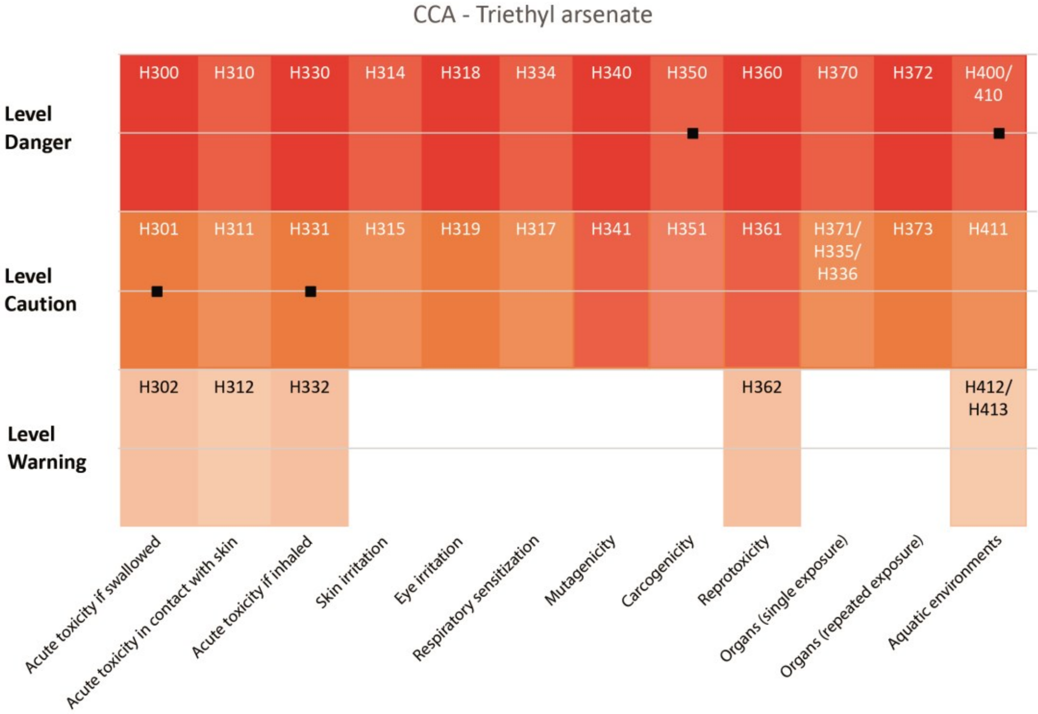
Diagram 5. Toxicity profile of arsenic derivatives that may be present in CCA





Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

The impacts of CCA on health and the environment are mainly dictated by the presence of arsenic: the various arsenic-based compounds that can be found in CCA are all classified as highly probable carcinogens (H350), some are confirmed reprotoxic (H360), and all can cause neurological disorders and are highly toxic to aquatic organisms.



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

Therefore, since 2004, European regulations have only authorized the use of arsenic for industrial applications, including wood treatment (in non-residential contexts) which are not intended to be in contact with the aquatic environment.

Similarly, in the United States, CCA treatments have been banned since 2003 for all residential uses just like in Australia.

Strong lobbying by citizen associations (the main one being Beyond Pesticides), backed by local communities, has been trying for several years to get CCA banned in the United States, without success to date.

These treatments are totally banned in Denmark, Switzerland, Vietnam, Indonesia, Israel and the United Kingdom (since 2006).

Consumer countries

CCA impregnation of utility poles is the most common treatment option in Africa and India.

Production

There are many manufacturers who produce CCA:

- Lonza (#1 producer worldwide) (Arxada, Wolman): Wolmanac CCA® and ET® in Europe and North America; Tanalith CCA® in Asia, Australia, New Zealand and South Africa.
- Koppers Performance Chemicals.
- Viance: SupaTimber®.
- Dolphin Bay: Permaccure CCA® in South Africa.

CCA treatment cannot be a medium-term alternative to creosote for treating utility poles. Even if the product is widely available and used, its toxicity is significant and proven.

Acceptability summary

CCA	
Summary in favor of ban	
Banned by WB NES 3	YES
Banned in Europe	NO
Banned in the US	NO
Risk of cancer, mutation, reprotoxicity	YES
National exclusions	Indonesia, Great Britain, Israel, Switzerland, Vietnam
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

The (already long-standing) widely used alternatives

8.1.3. Copper naphthenate

Reference

Copper naphthenate ($C_{14}H_{10}CuO_4$)	**ECHA**	215.657.0	**CAS**	1338-02-9

Description

Copper naphthenate is a product that is increasingly used in the United States but much less so in Europe, and is presented as an alternative to older products. It is obtained by reacting copper (known for its fungicidal properties) with naphthenic acid, which is a petroleum derivative.

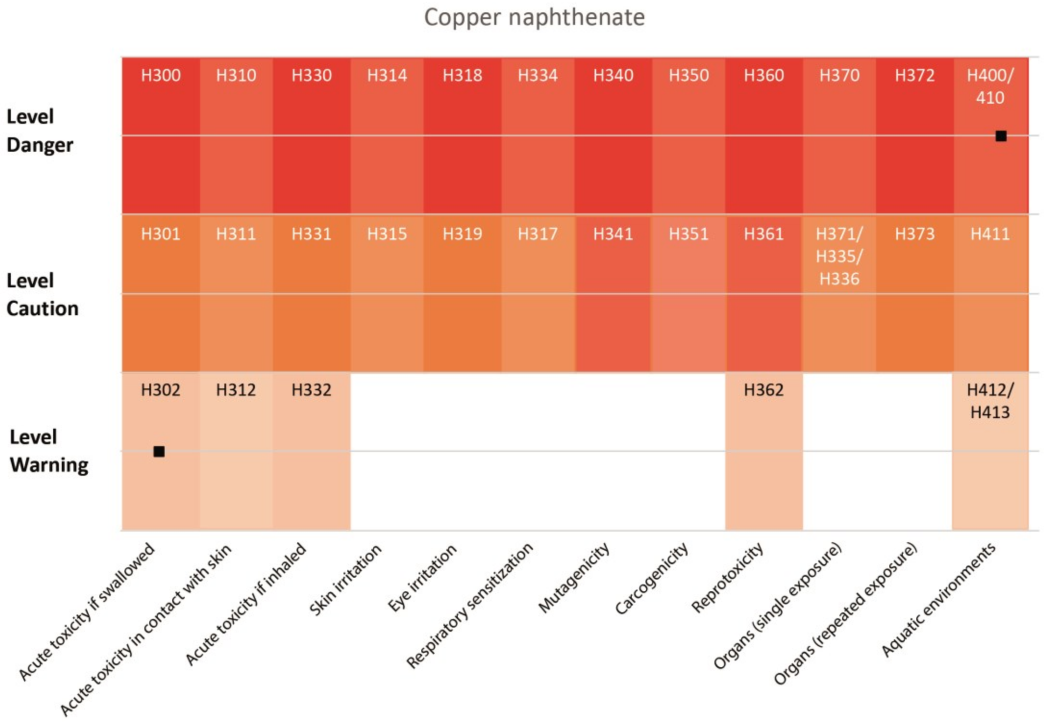
Not very soluble in water, naphthenate is mixed with oily solvents before impregnating the wood. It is recognized as being as effective as creosote.

Toxicity and ecotoxicity

Although not well documented, this substance is recognized as an irritant and therefore requires protection when handled. When it is highly concentrated, it can even be very dangerous. It is also flammable and releases toxic fumes when burned.

It is simply declared harmful if absorbed in any form (H302, H312, H332). It is also recognized as very toxic to aquatic organisms with long-lasting effects. However, it is considered ten times less toxic than pentachlorophenol, but is also slightly less effective.

Diagram 6. Toxicity profile of copper naphthenate



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

In the United States, copper naphthenate has been registered by the EPA since 1951. It is not listed as a hazardous substance under the *Clean Air Act* and is not listed as a hazardous insecticide or hazardous waste under the *Clean Water Act.*

It is not subject to any particular restriction in Europe.

It cannot be used in countries that have banned the use of copper as a fungicide such as Denmark, Norway, and the Netherlands.

Consumer countries

Copper naphthenate is extensively used in the U.S., including by leading wood treatment companies (Stella-Jones), and will benefit from a windfall effect following the ban on pentachlorophenol (Koppers announced in 2020 that it would use it as an alternative to pentachlorophenol). More than one million poles were treated with this product during the 1990s.

It is also frequently used in Japan.

The consumption of copper naphthenate in Europe does not exceed a few tens of tons, so it is not a very common product for treating power poles.

Production

Note that there are several producers:

- in the U.S.: Nisus: QNAP®, Strem Chemicals, Troy: Troysan.
- as well as in the United Arab Emirates (Optichem), India, China (Minghuan Chemical, Zhang Ming Chemical) and Japan (Nihon Merichem).

Copper naphthenate treatment remains a highly ecotoxic treatment option.

Acceptability summary

Copper Naphthenate	
Summary in favor of ban	
Banned by WB NES 3	NO
Banned in Europe	NO
Banned in the US	NO
Risk of cancer, mutation, reprotoxicity	NO
National exclusions	Denmark, Norway, Netherlands
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

8.1.4. Ammoniacal copper zinc arsenate (ACZA)

Reference

Copper oxide (11%)	**ECHA**	215.270.7	**CAS**	1317-39-1
Zinc oxide (5.5%)	**ECHA**	215.222.5	**CAS**	1314-13-2
Arsenic pentoxide (5.5%)	**ECHA**	215.116.9	**CAS**	1303-28-2

Description

ACZA, better known by one of its trade names, chemonite, is an aqueous combination of copper (for its fungicidal properties), arsenic (for its insecticidal properties), and ammonia (which facilitates penetration into the wood). It has been used since the 1990s mainly in North America.

It is particularly well suited for hardwood species.

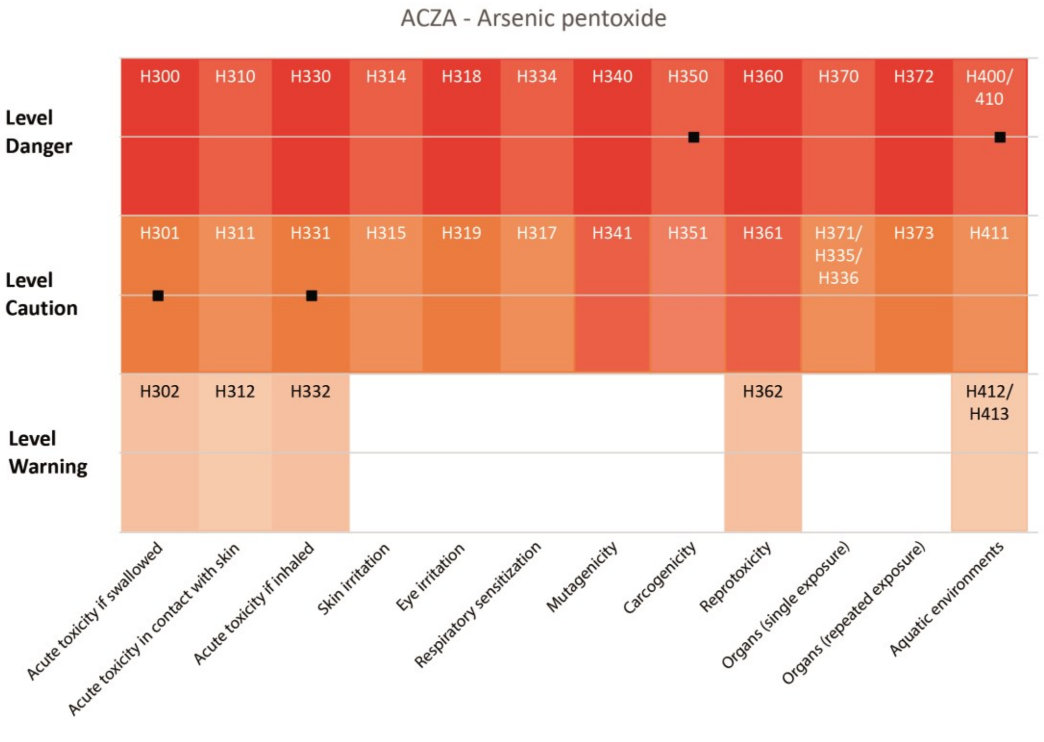
Since it contains ammonia, it is corrosive to certain metals and therefore to certain fastening systems attached to the poles.

Toxicity and ecotoxicity

Just as with CCA, the presence of arsenic makes it a hazardous product for human health and the environment.

In the United States, ACZA is recognized as a carcinogen (because it contains arsenic pentoxide, which is recognized as a definite carcinogen), corrosive to the skin, irritating to the skin, eyes, and respiratory tract.

Diagram 7. Toxicity profile of ACZA's components



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

In the United States, ACZA is a restricted use pesticide by regulation (FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act).

Consumer countries

ACZA is widely used in the United States. However, because of its toxicity, its use has declined in other countries such as Canada.

It is not widely used in Europe..

Production

ACZA is produced in the United States by Archwood (Lonza) and in China by several manufacturers including Foshan Liyuan Chemicals. Although invented in Canada, ACZA was discontinued in that country in 2006.

CZA treatment is not an alternative to creosote for treating utility poles. Even if the product is widely available and used, its toxicity is significant and proven, as well as its carcinogenicity.

Acceptability summary

ACZA		
Summary in favor of ban		
Banned by WB NES 3		YES
	Banned in Europe	NO
	Banned in the US	NO
	Risk of cancer, mutation, reprotoxicity	YES, H350
National exclusions		
Summary in favor of acceptance, but...		
Summary in favor of acceptance		

Newer alternative products

8.1.5. Dichlorooctyl-isothiazolinone (DCOI)

Reference

DCOI	**ECHA**	264.843.8	**CAS**	64359-81-5

Description

Dichlorooctyl-isothiazolinone (4,5-dichloro-2-octyl-2H-isothiazol-3one) is a newer substance, registered with the EPA in 1996, and is oil-like in that it is mixed with solvents for use. DCOI is sold because of what it does not contain: no dioxins, heavy metals, or PAHs.

The wood is treated with DCOI by pressure impregnation with a retention rate between 1.6 and 3.2 kg/m^3.

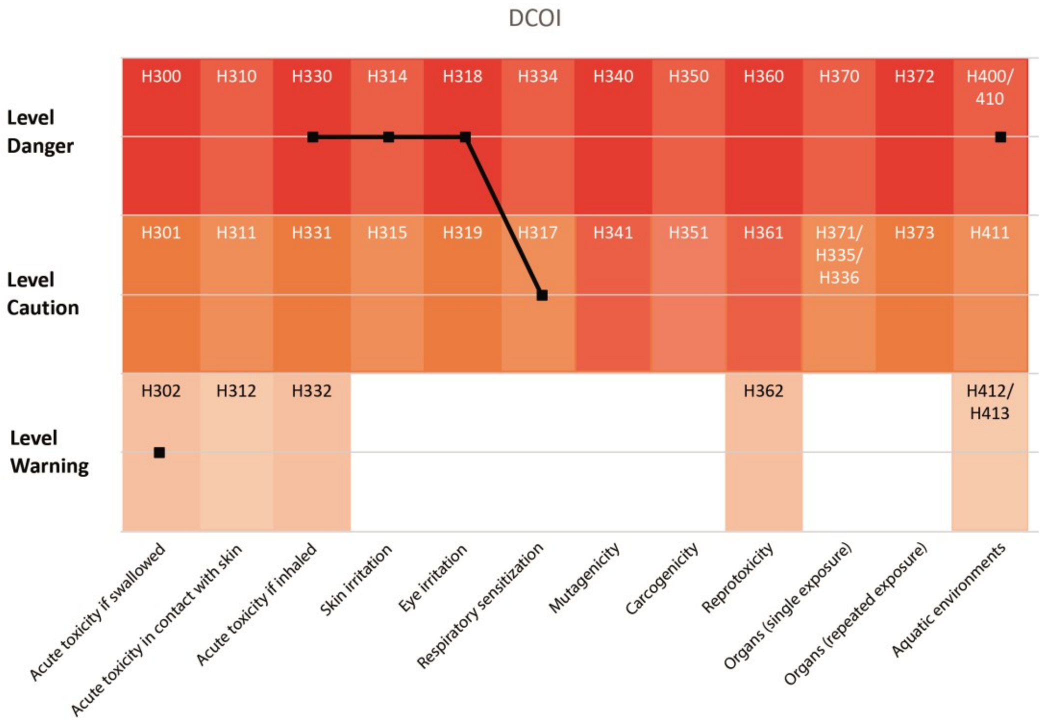
Toxicity and ecotoxicity

DCOI is classified as hazardous to human health in several ways: it is classified as hazardous to swallow (H302) and hazardous to inhale (H330), highly irritating to skin and eyes (H314), and highly toxic to aquatic organisms (H410).

The evaluation report, conducted by ECHA in 2014[14], mentions the lack of a specific study on the substance's carcinogenicity, but assumes that DCOI is not carcinogenic because this property is not present in the three isothiazolinones making up DCOI. In addition, no repro-toxicity or endocrine disrupting properties were found.

On the other hand, the substance (DCOI) is not very soluble and persistent in soils (half-life[15] of 4.7 days), in water (half-life of 16.5 days), or in sediments (half-life of 4 days).

Diagram 8. Toxicity profile of DCOI



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

No special regulations.

The United States authorized DCOI in 2017 for soil contact uses.

In addition, Europe conducted an impact assessment in 2011 that concluded that DCOI could be allowed for industrial applications.

[14] http://dissemination.echa.europa.eu/Biocides/ActiveSubstances/0022-21/002221_Assessment_Report.pdf

[15] The term "half-life" here refers to the time it takes for a substance to lose half of its physiological activity. The term is therefore misleading, as it is not used to refer to half a lifespan.

Consumer countries

The United States has a substantial utilization rate of DCOI.

Production

Koppers (Ex-Osmose), Viance (Ultrapolenxt® and Ultraarmnxt®), Sigma-Aldrich (Merck Group) and Foshan Liyuan are major producers of this substance. Viance is also a very active developer and lobbyist in the United States for DCOI. Viance petitioned the EPA in 2020 to have DCOI treated products not be considered hazardous.

CCA treatment cannot be a medium-term alternative to creosote for treating utility poles. Even if the product is widely available and used, its toxicity is still significant and proven.

Acceptability summary

DCOI	
Summary in favor of ban	
Banned by WB NES 3	NO
Banned in Europe	NO
Banned in the US	NO
Risk of cancer, mutation, reprotoxicity	NO
National exclusions	
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

8.1.6. Alkaline copper quaternary (ACQ)

Reference

Boric acid	**ECHA**	233.139.2	**CAS**	10043-35-3
Quaternary ammonia	**ECHA**	269.919.4	**CAS**	68391-01-5
Quaternary ammonia	**ECHA**	230.525.2	**CAS**	7173-51-5

Description

Alkaline copper quaternary is an aqueous mixture of 50-67% copper oxide and 33-50% quaternary ammonium compound to facilitate penetration of the product into the wood.

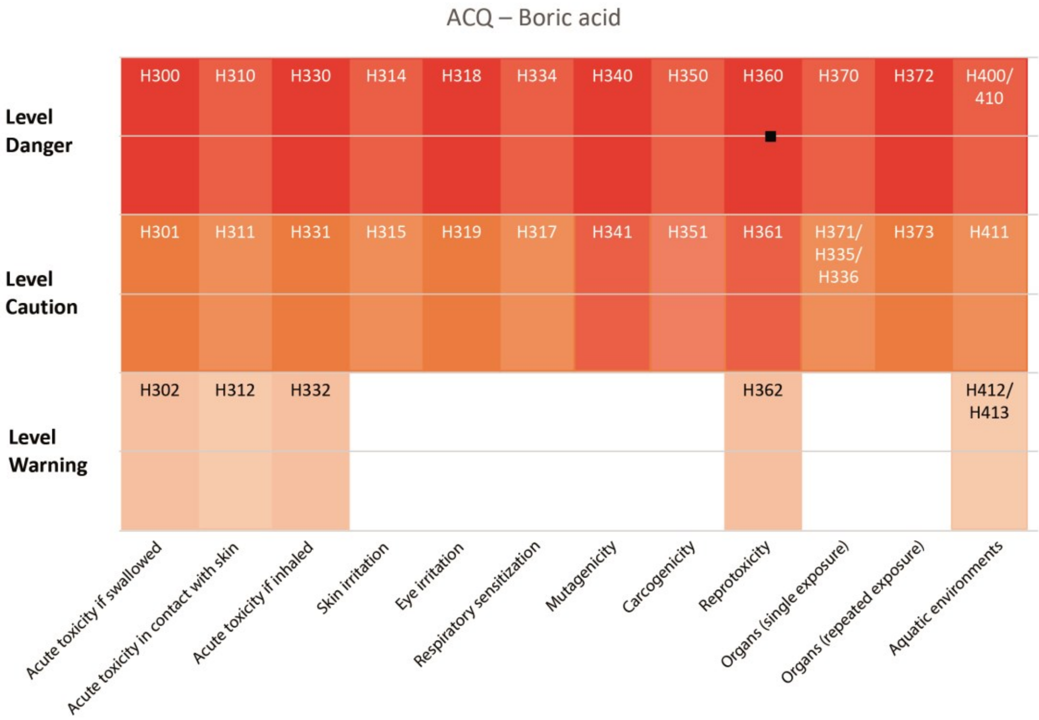
Registered with the EPA in 1985 and first commercially produced in Canada in 2004, ACQ is one of the newer wood treatment solutions and is approved for consumer use.

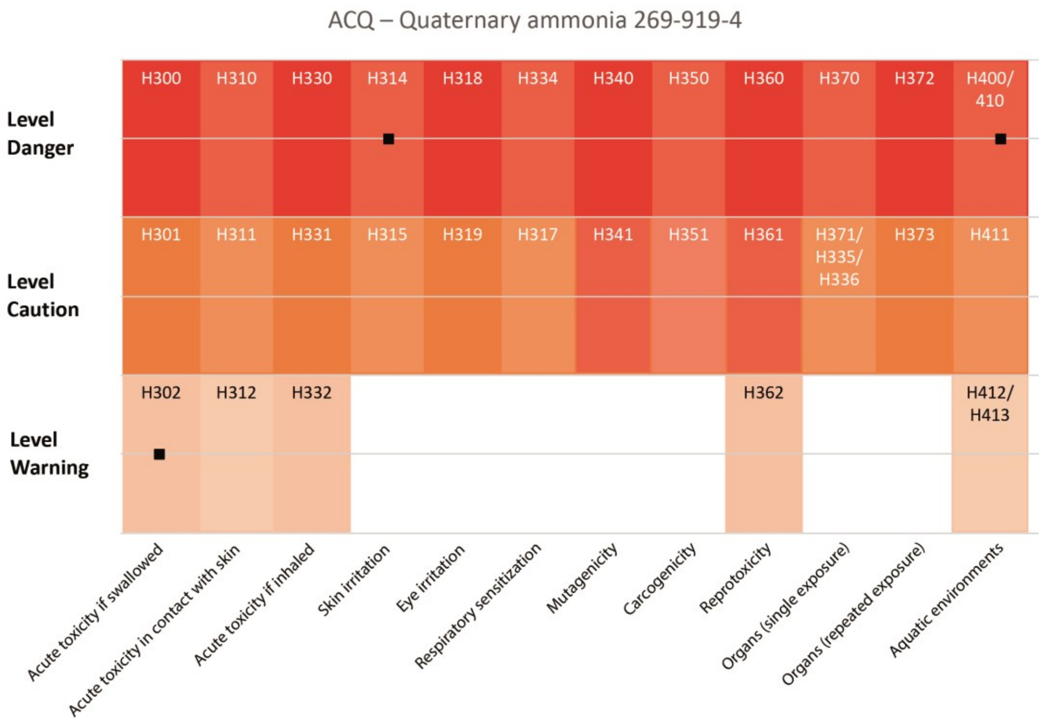
ACQ provides very satisfactory protection results, similar to those of CCA. ACQ is also sold based on what it does not contain (chromium and arsenic).

Toxicity and ecotoxicity

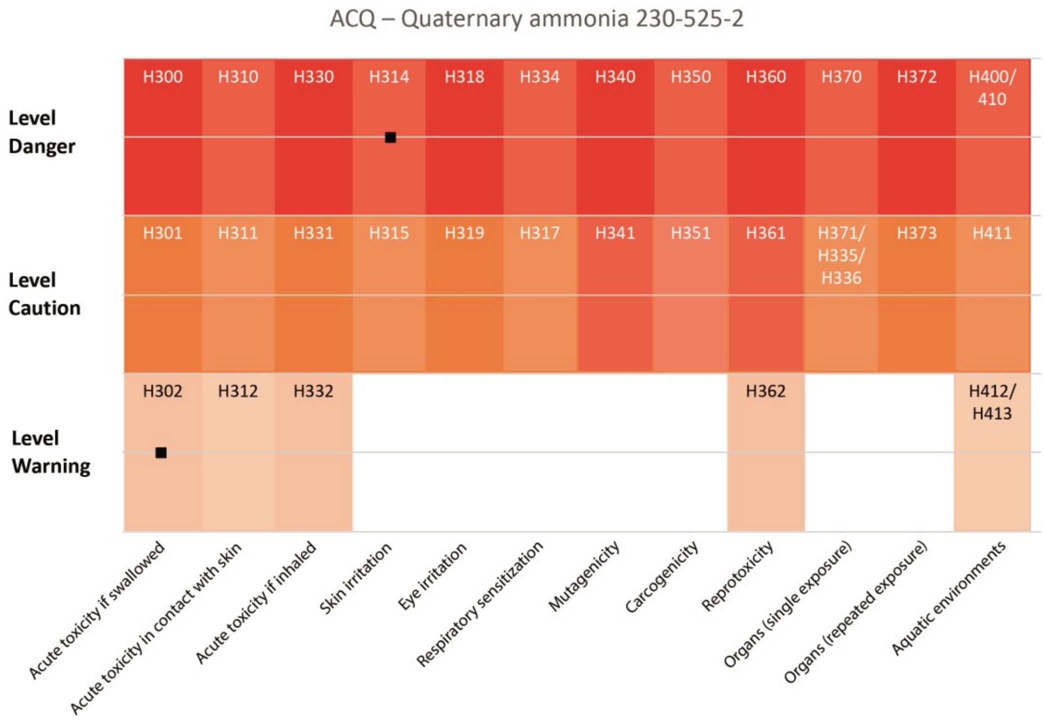
ACQ is a product classified as harmful if swallowed, inhaled, or in contact with skin. It is a skin and eye irritant requiring precautions when handling. It is also a carcinogen and is likely to be reprotoxic as is one of its main components, boric acid.

Diagram 9. Toxicity profile of ACQ's components





Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

No special regulations.

Consumer countries

On the other hand, the product is very corrosive (because of the ammonia) and requires choosing fastening systems and attachments to the poles that are suited to its properties, otherwise it will deteriorate rapidly.

It is now a widely used product in the United Kingdom, deployed in Europe, the USA, Japan, Australia, and New Zealand.

Production

In the U.S.:

- Viance: Preserve ACQ®
- Koppers: Naturewood® ACQ®

In South Africa:

- Dolphin Bay: Permacure ACQ®

In India:

- Dattashri: Amquat SS211®

Acceptability summary

ACQ	
Summary in favor of ban	
Banned by WB NES 3	YES
Banned in Europe	NO
Banned in the US	NO
Risk of cancer, mutation, reprotoxicity	YES, H360
National exclusions	
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

8.1.7. Triadimefon

Reference

Triadimefon	**ECHA**	256.103.8	**CAS**	43121-43-3

Description

Triadimefon was unveiled in 1976 and quickly used because of its systemic, broad-spectrum antifungal properties. It belongs to the conazole pesticides category along with propiconazole, a component of tannalith E (see Section 11.1.9).

Toxicity and ecotoxicity

The EPA's main focus is the neurotoxic nature of triadimefon, which has been demonstrated in numerous laboratory experiments with animals.

Triadimefon is also suspected of being a carcinogen (it is classified as a category C carcinogen in the United States) and an endocrine disruptor (it is listed as such by Europe and the WWF [16]).

The impact of triadimefon on aquatic organisms was initially estimated as moderate before field observations in China, where triadimefon is widely used, showed much more harmful effects.

[16] World Wildlife Fund.

Diagram 10. Toxicity profile of triadimefon

Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

In 2006, the EPA dramatically reduced the allowable use cases for triadimefon, excluding all domestic and agricultural uses.

Triadimefon is banned in Europe for food and agricultural uses.

Consumer countries

Since 2006, the use of triadimefon has been greatly reduced in the United States. However, it continues to be used extensively in China, particularly for agricultural purposes.

Production

Sigma-Aldrich is a producer of the substance, as are several Chinese manufacturers.

Acceptability summary

Triadimefon		
Summary in favor of ban		
Banned by WB NES 3		YES
	Banned in Europe	For certain uses
	Banned in the US	NO
	Risk of cancer, mutation, reprotoxicity	Endocrine disruptor
National exclusions		
	YES, but...	
Summary in favor of acceptance		

8.1.8. Disodium octoborate tetrahydrate (DOT)

Reference

Disodium octoborate tetrahydrate (DOT)	**ECHA**	234.541.0	**CAS**	12280-03-4 (tetrahydrate version) 12008-41-2 (anhydrite version)

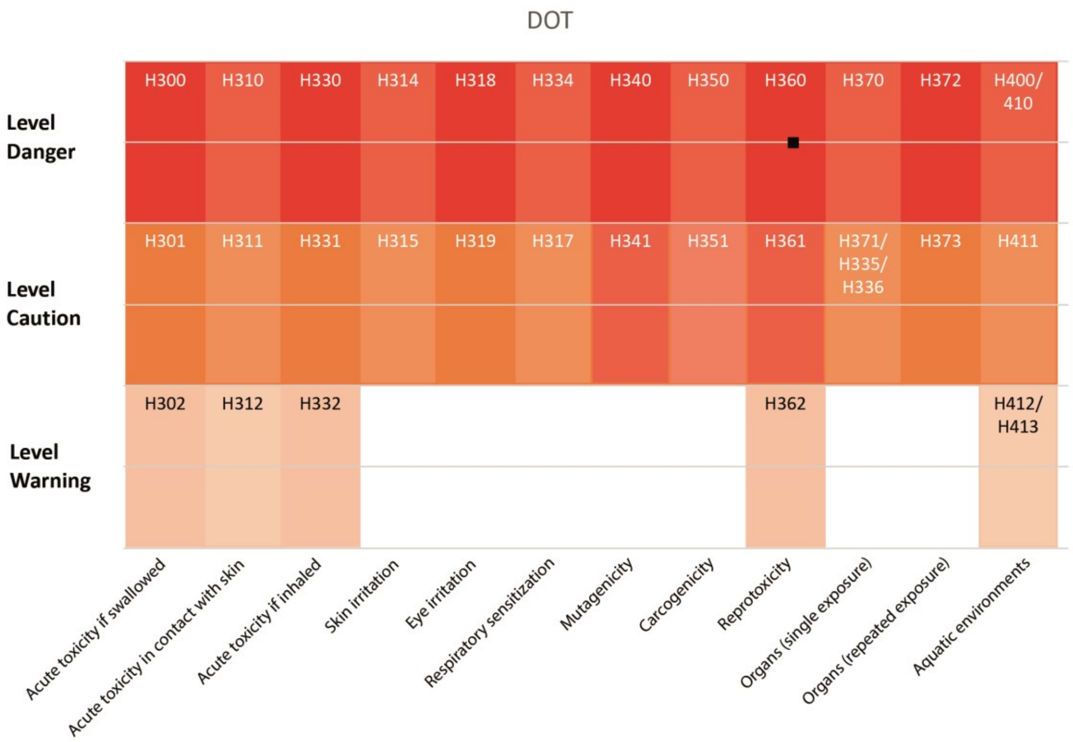
Description

Disodium octoborate tetrahydrate is a boric compound widely used in industry. It is not degradable when in its natural state, is highly soluble in water (making it suitable for use as a spray), and has a low bioaccumulation potential.

Toxicity and ecotoxicity

DOT is classified as H360FD: it is recognized as being highly toxic to unborn children. It is also classified as corrosive to the skin (H319) and irritating to the respiratory tract (H335).

Diagram 11. Toxicity profile of DOT



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

Due to its reprotoxic properties, DOT is not authorized as a pesticide in Europe or Switzerland, but continues to be authorized for use in the manufacture of sealants, modeling compounds, and plasters.

Consumer countries

Several thousand tons of DOT are consumed annually in Europe, but not as a pesticide.

Its use in wood treatment is common in the United States and China.

Production

In the United States, DOT is produced by Koppers (Advance Guard® and Hi-Bor®), American Borate Company (Etidot 67®), and Viance (TimberSaver®).

DOT is also produced by several manufacturers in India and China.

Acceptability summary

DOT	
Summary in favor of ban	
Banned by WB NES 3	YES
Banned in Europe	NO
Banned in the US	NO
Risk of cancer, mutation, reprotoxicity	YES, H360
National exclusions	
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

8.1.9. Tanalith® E

Reference

Propiconazole	**ECHA**	262.104.4	**CAS**	60207-90-1
Copper carbonate	**ECHA**	235.113.6	**CAS**	12069-69-1
Copper	**ECHA**		**CAS**	7440-50-8
Tebuconazole	**ECHA**	403.640.2	**CAS**	107534-96-3
Ethanolamine	**ECHA**	205.483.3	**CAS**	**141-43-5**

Description

Tanalith® E is an aqueous mixture for pressure treating wood with a retention rate between 17 and 28 kg/m^3 depending on the type of wood.

It was developed by Arch (now a subsidiary of Lonza).

Toxicity and ecotoxicity

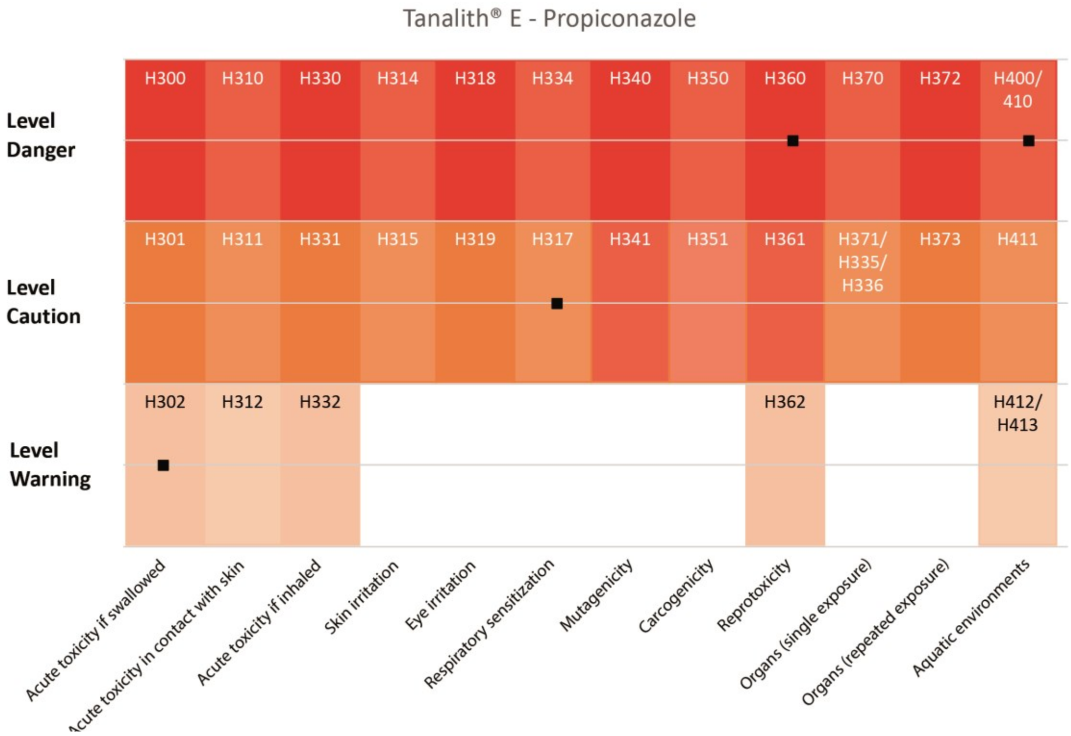
For Europe, some components of Tanalith® E are problematic because their impact on human health is not negligible.

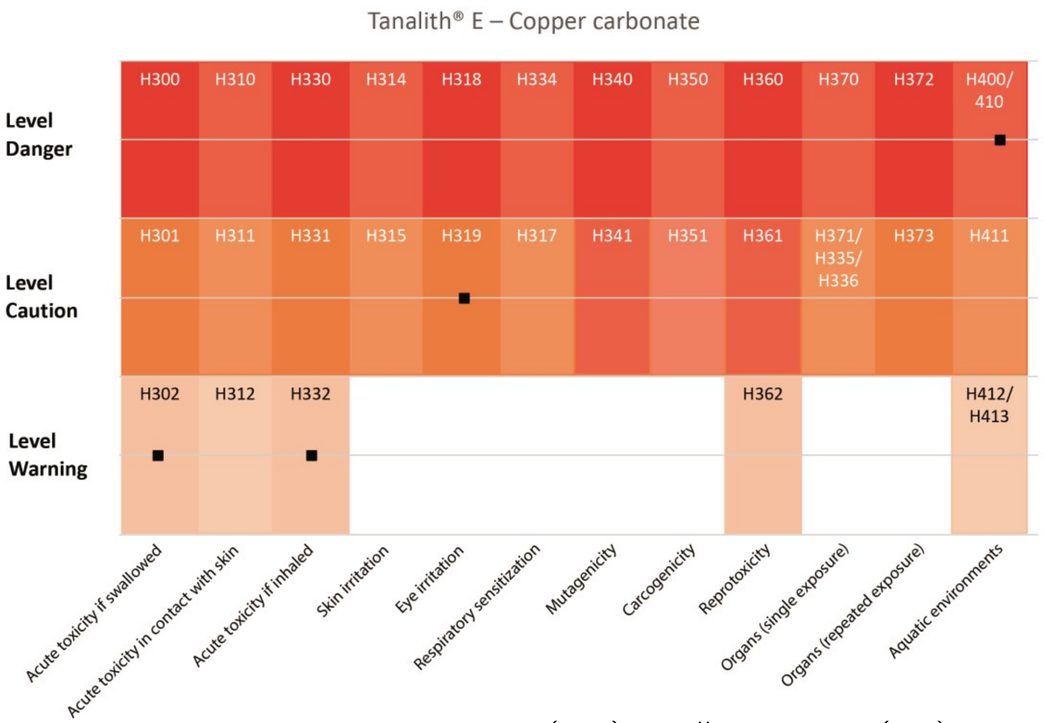
For example, 2-Aminoethanol is classified as harmful if swallowed (H302) or through contact (H312), corrosive to the skin (H314), and irritating to the respiratry tract.

Tanalith® E contains propiconazole, a reprotoxic fungicide banned by the European Commission since 2021.

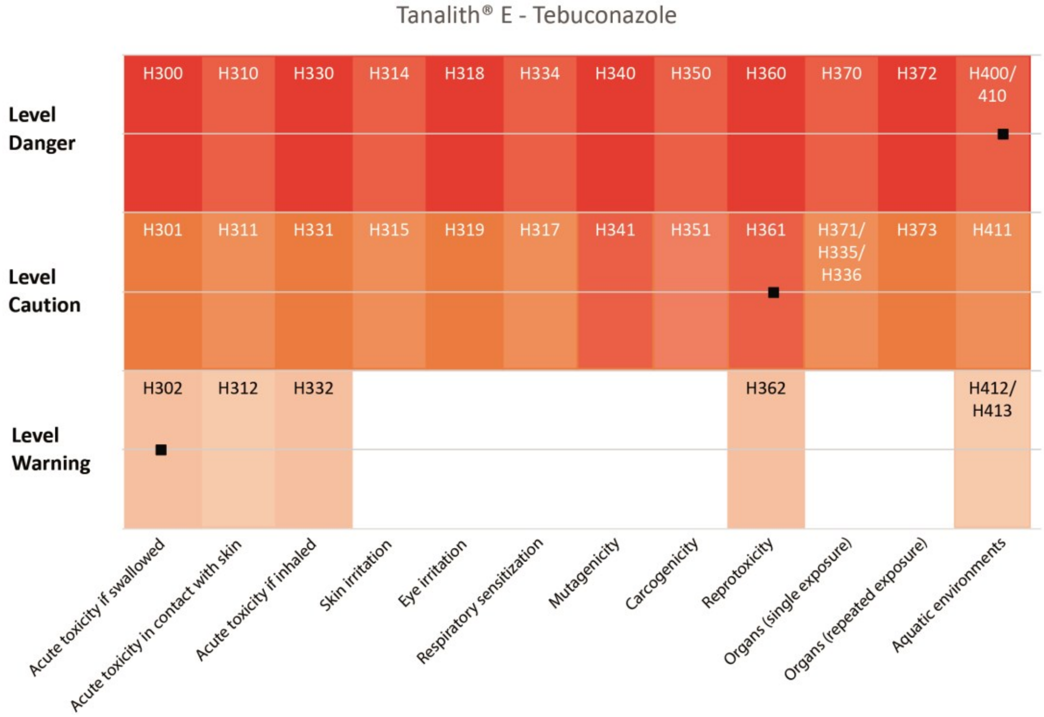
Its presence independently indicates risks identified directly concerning Tanalith® E, classified as harmful if swallowed (H302) or through contact (H312), irritating to the eyes (H318), irritating to the respiratory tract, and finally very toxic to aquatic organisms (H410).

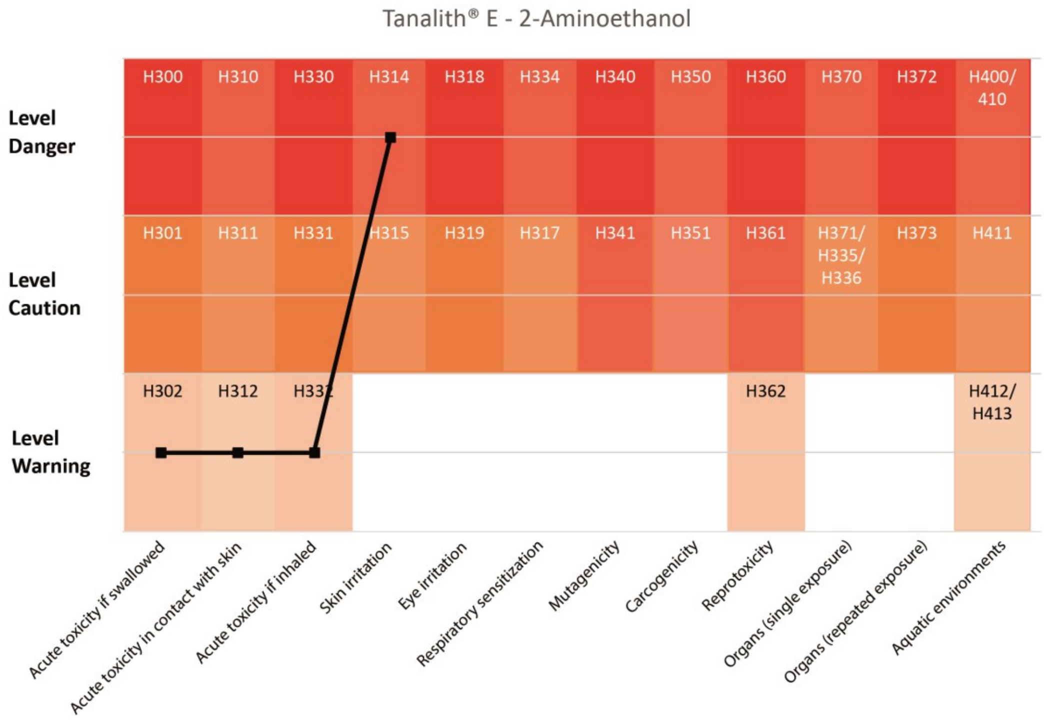
Diagram 12. Toxicity profile of Tanalith® E





Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).





Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

Tanalith® E has been evaluated by the European Union and has not been banned as a wood preservative.

Consumer countries

Tanalith® E is widely used in Asia, Australia, New Zealand and South Africa. Lonza limits its use to these countries, preferring to promote CCA and ACZA-based solutions for Europe and North America at this time. It is, however, used in Europe..

Production

Tanalith® E is a product developed and produced by Lonza (Arxada).

Acceptability summary

Tanalith® E	
Summary in favor of ban	
Banned by WB NES 3	YES
Banned in Europe	NO
Banned in the US	NO
Risk of cancer, mutation, reprotoxicity	YES, H360
National exclusions	
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

8.1.10. Koppers Celcure® AC 500

Reference

Copper carbonate	**ECHA**	235.113.6	**CAS**	12069-69-1
Boric acid	**ECHA**	233.139.2	**CAS**	10043-35-3

Description

Koppers Celcure AC 500® is an aqueous mixture developed by Koppers exclusively for treating wood.

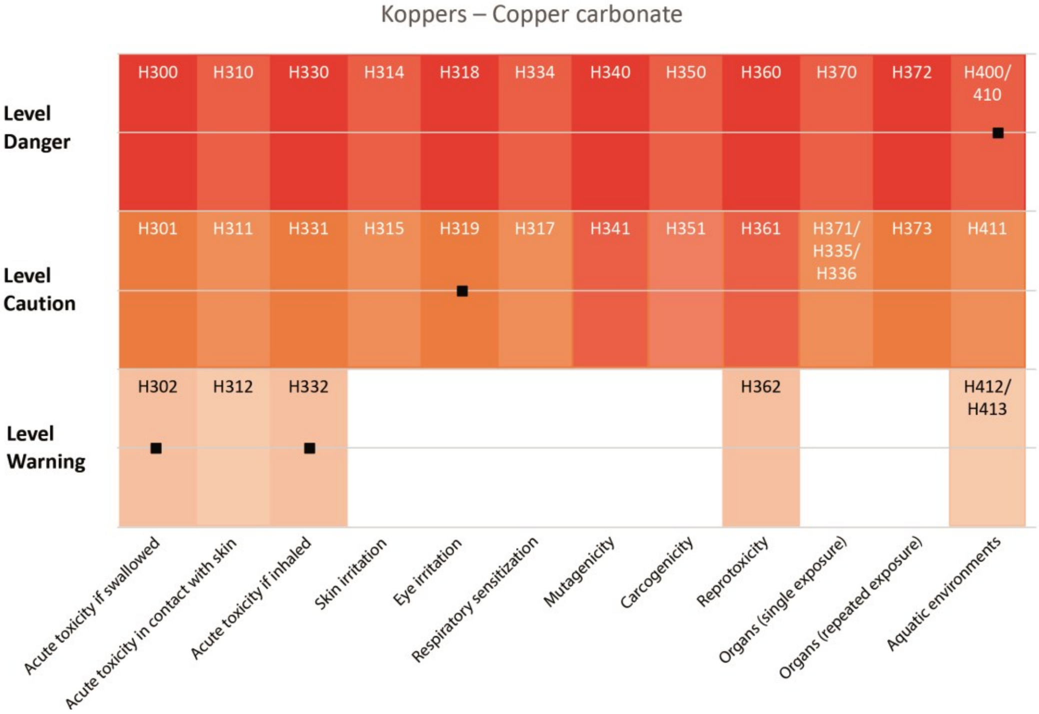
Toxicity and ecotoxicity

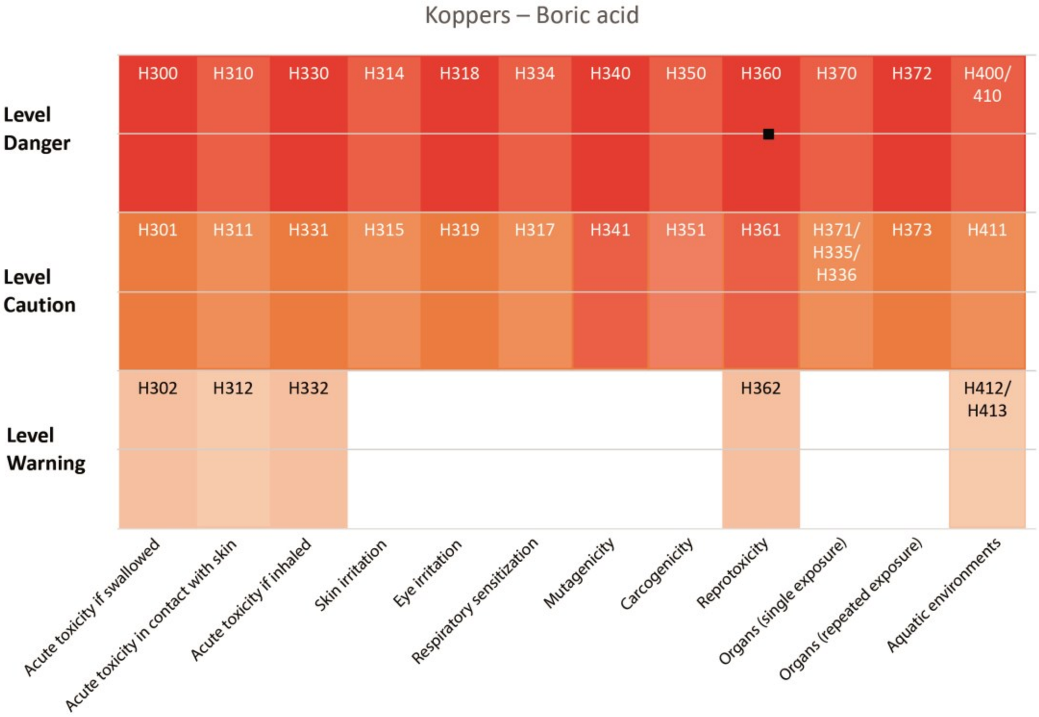
The main components of Koppers Celcure AC 500® have a significant impact on human health:

- copper carbonate is harmful if inhaled or swallowed (H302, H332) and very toxic to aquatic organisms (H400, H410).
- boric acid is a reprotoxic (H360FD).

However, the low doses in which these constituents are found in Celcure® mitigate their effects. The only classification that has been applied to Celcure® is harmful to aquatic organisms (H412).

Diagram 13. Toxicity profile of the Koppers Celcure® AC 500's components





Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

From 2015 to 2020, the United Kingdom was in charge of evaluating Celcure® for approval on behalf of the European Union. During this period, the product's authorization was continuously renewed.

Since 2020, after the United Kingdom's withdrawal from the EU (Brexit), Sweden has been responsible for this assessment. Since the assessment study was not completed, a transitional authoriza-tion was granted to Celcure® in June 2021 and its renewal depends on the outcome of the findings of the Swedish study.

Consumer countries

The product is consumed in many countries located on five continents.

Production

The Koppers Celcure® AC 500 is manufactured by Koppers.

Acceptability summary

Koppers AC 500		
Summary in favor of ban		
Banned by WB NES 3		YES
	Banned in Europe	NO
	Banned in the US	NO
	Risk of cancer, mutation, reprotoxicity	YES, H360
National exclusions		
Summary in favor of acceptance, but...		
Summary in favor of acceptance		

8.1.11. Wolmanit® CX-F

Reference

Copper carbonate Cu HDO Ethanolamine	**ECHA** **ECHA** **ECHA**	235.113.6 608.595.4 205.483.3	**CAS** **CAS** **CAS**	12069-69-1 312600-89-8 141.43.5

Description

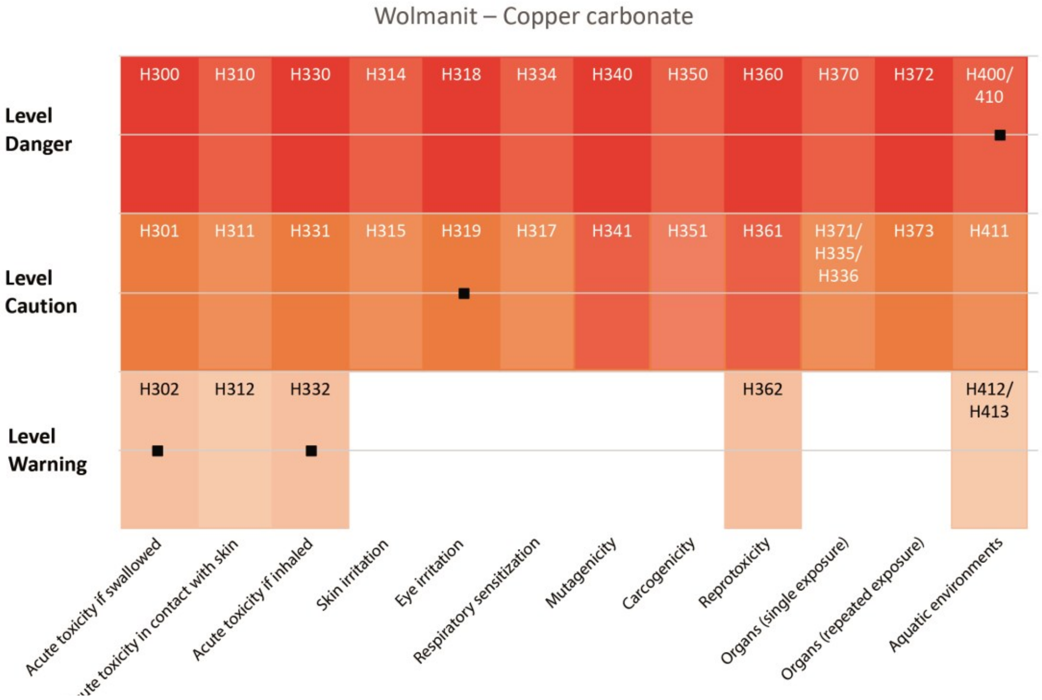
Wolmanit® CX-F is a patented aqueous solution based on 2.8% HDO copper and approximately 13% copper carbonate.

Toxicity and ecotoxicity

Like all equivalent products, Wolmanit® is a toxic product for the environment, especially for aquatic organisms, and therefore requires precautionary measures.

It is also a corrosive and irritant.

Diagram 14. Toxicity profile of Wolmanit® CX-F's components



Source: European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

Regulations

No special regulations for this product.

Consumer countries

Wolmanit® is used in many countries, especially in Europe. The continent where it is least widespread is probably North America.

Production

Wolmanit® CX-F is a product developed and produced by BASF Wolman.

Acceptability summary

Wolmanit® CX-F	
Summary in favor of ban	
Banned by WB NES 3	NO
Banned in Europe	NO
Banned in the US	NO
Risk of cancer, mutation, reprotoxicity	NO
National exclusions	
Summary in favor of acceptance, but...	
Summary in favor of acceptance	

8.1.12. Organic products

Given the numerous bans on fungicides and insecticides for residential use, alternative wood treatment methods have been developed to meet these markets.

The principle is to modify the internal structure of the wood to change its properties, rather than impregnating the wood with a preservative.

Chemical methods have been explored but, to date, none have been developed industrially because the treatments are too expensive (acetylation, furfurylation, DMDHEU treatment).

On the other hand, various heat treatment processes for wood have been developed in Canada, Finland, France, and the Netherlands. They are all based on a treatment cycle principle (high temperature - drying - high temperature) and differ in the pressure or atmosphere (air, neutral atmosphere, nitrogen and carbon dioxide) in which the treatment is done.

These include the Thermowood, Plato, and Retification processes.

All have proven to be effective in protecting wood from mold and insects in different climates. However, they have not been used for utility poles, and we have not collected economic data to confirm the value of these solutions.

8.1.13. Price comparison

As already mentioned, the choice of wood treatment product does not have a significant impact on the design of the poles, nor on their manufacture or installation.

However, there are price differences between these substances. The cost of treated wood varies depending on the cost of the substance but also on the amount of substance needed to treat the wood. Thus, an initial comparison is as follows:

Table 4. Price comparison of wood treated with different biocides

Treatment substance	Price of the substance (EUR/kg)	Retention (kg/m^3)	Cost of wood treatment (EUR/m^3)
ACQ	2.8	6	16.8
CCA	2.8	6	16.8
Wolmanit CX-S	4.7	4	18.8
ACZA	3.8	6	22.8
Tanalith® E	3.8	6	22.8
Koppers AC 500	3.8	6	22.8
Creosote	0.75	100	75

Source: Mach&Team according to the European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

The cost of the treatment should be added to the cost of the raw wood to get the net cost of the treated pole.

This comparison can explain differences in sales prices between timber poles treated with different substances.

Wood poles, compared to other alternatives, which will be discussed in the next chapter, often have a lower retail price than poles made with other technologies or materials, but it is important to consider the final cost at different levels:

- the sales price of wooden poles is generally very competitive. However, its competitiveness may vary depending on whether the post is manufactured locally from local raw wood (favorable scenario) or is imported from distant producing countries (unfavorable scenario) as is the case in some Middle Eastern desert countries.
- the price of the installed pole, consisting of the above-mentioned sales price and the installation price, depending for example on the weight of the pole or the difficulty of attaching accessories (e.g. crosspieces, cable supports, etc.). At this stage, poles remain competitive, but their competitiveness is limited by installation costs that remain quite high. The systems for attaching accessories to steel, composite or concrete poles are made in the factory, whereas wood poles require drilling which is often done during installation.
- the total cost of ownership which represents all the costs generated by the pole throughout its life cycle (possibly including the recycling costs). This tier, like the previous one, takes into account new costs that are not very favorable to wood poles: indeed, these poles require more maintenance and inspections than others, and can therefore often have a shorter lifespan.

Therefore, it is important not to assess the cost of utility poles by simply looking at their sales price.

8.1.14. Toxicity comparison

The above review of the various substances used for treating wood demonstrates that no industrial pesticide or fungicide is hazard-free. Metals used because of their natural - (copper, arsenic, and chromium) have impacts on human health and on the environment that are just as significant as industrial derivatives (boric compounds, conazoles, and pentachlorophenol).

No substance offers an obvious alternative to creosote and some even have similar impacts.

The trend in industrial countries (Europe leading the pack) is to progressively limit the use of these substances. The United States is now more permissive but is following suit. On the other hand, China and India continue to be major producers and consumers of these substances, which they can easily export to all countries whose regulations do not prohibit it.

Almost all of these products are very toxic, in the short and medium term, for aquatic organisms. Their use must be strictly limited or even forbidden, like wood treatment in bodies of water and rivers.

We can then suggest the following comparison based on three categories of criteria:

- carcinogenic, mutagenic, reprotoxic or endocrine disrupting products (or those strongly suspected of being so) must be banned.
- products with very high toxicity (assessed in terms of the hazard level shown in red on the toxicity profiles) may be prohibited or, otherwise, be subject to special protection measures (i) for persons likely to be in contact with these products, and (ii) for the environment, during their use.
- irritants must be handled, transported, and stored with care.

The analysis made based on these criteria leads to a major warning on most of the products, which are not acceptable with regard to their properties (highlighted in red in Table 5), with the exception of copper naphthenate, IOCD, and Wolmanit CX (which is only manufactured by BASF-Wolman).

Table 5. Comparative toxicity of different wood treatment products

Wood preservative	Creosote	Pentachlorophenol	CCA	DCOI	ACQ	Copper Naphthenate	ACZA	Triadimefon	DOT	Tanalith® E	Koppers AC 500	Wolmanit® CX-F
Toxicity to aquatic organisms	1	1	1	1	1	1	1	2		1	1	1
Carcinogenic product	2	1	1				1					
Mutagenic product												
Reprotoxic or endocrine-disrupting product			1		1			1	1	1	1	
Toxicity	1	2	1	1	3	3	2	3		3	3	3
Irritating to skin	2	2		1	1					1		
Irritating to eyes	2	2		1						2		1
Irritating to the respiratory tract				2				2		2		

Source: Mach&Team according to European Chemicals Agency (ECHA) – http://echa.europa.eu (2022).

8.2. STEEL

Steel is a material commonly used for electrical towers supporting transmission lines, more rarely for power grids.

It makes several design variations possible:

- various shapes (welded mesh or single-pole and, among the single-pole posts, twelve-sided or round).
- various finishes (galvanized steel, weathering steel, painted steel).

They can be adapted to the landscape and are sometimes more discreet than wooden posts.

Photo 1. Example of a metal lattice pole

Photo 2. Example of a single metal pole

8.2.1. Physical properties

Steel poles are generally lighter than wood poles. Depending on the source, weight savings range from 30 to 70% **in the most favorable cases**. However, these figures cannot be taken as a reference.

Some types of steel poles may be heavier. The weight data used in the various available studies should be regarded with caution because the authors of the publications providing weight comparisons between wood and steel poles naturally choose the conditions and factors that are favorable to the argument they are making.

Thus, the WEI-IEO, a European trade association representing the wood processing industry, seeks to show the advantages of wood poles and provides the following comparison:

Table 6. Weight comparison of steel and wood poles

Pole height (m)	Type	Weight of wood pole (kg)	Weight of steel pole (kg)
8	L	143	262
8	M	157	374
10	M	259	471
10	S	395	879
12	M	356	601
12	S	539	1,068
14	S	686	1,311
18	S	1,110	2,322

Source: based on data from SEA Full Report, WEI-IEO (Brussels), August 2016.

In 2021, the Oak Ridge National Laboratory (ORNL) in the U.S., perhaps more neutrally, uses a 12.5-meter high reference pole:

- a wood pole weighs 1,315 kg.
- a steel pole weighs 631 kg.

Beyond the examples given, almost everyone agrees that steel poles are between 30 and 50% lighter than wood poles. This range should be considered representative in 95% of cases.

8.2.2. Advantages and disadvantages of steel poles

Steel poles have some significant advantages over treated wood poles:

- they are more easily transported because they are lighter. This can be important when shipping conditions are difficult.
- they are fire resistant.
- they are resistant to insects.
- during use, they do not pose a danger to human health or the environment.
- their physical properties are stable.
- they require little maintenance.
- inspecting them is neither destructive nor invasive to the pole.
- they are 100% recyclable.
- they are usually repairable after an impact caused by a vehicle, for example.

- it is easy to make holes in them for line brackets or any other accessory.
- their service life can reach 80 years.
- they can withstand stresses and shocks.

On the other hand, they have disadvantages:

- their manufacture requires non-renewable resources (metals).
- they have a worse carbon footprint than wood poles.
- they are expensive.
- they can be subject to corrosion in an acidic or saline atmosphere.
- they must be separated from the line brackets by a sufficiently effective insulator to be isolated from possible short circuits.
- they are more difficult to climb and work at the top of the poles requires either a cherry picker or specific equipment.
- it is advisable to avoid installing them on soils with acid sulphates.
- their shipping requires special precautions.

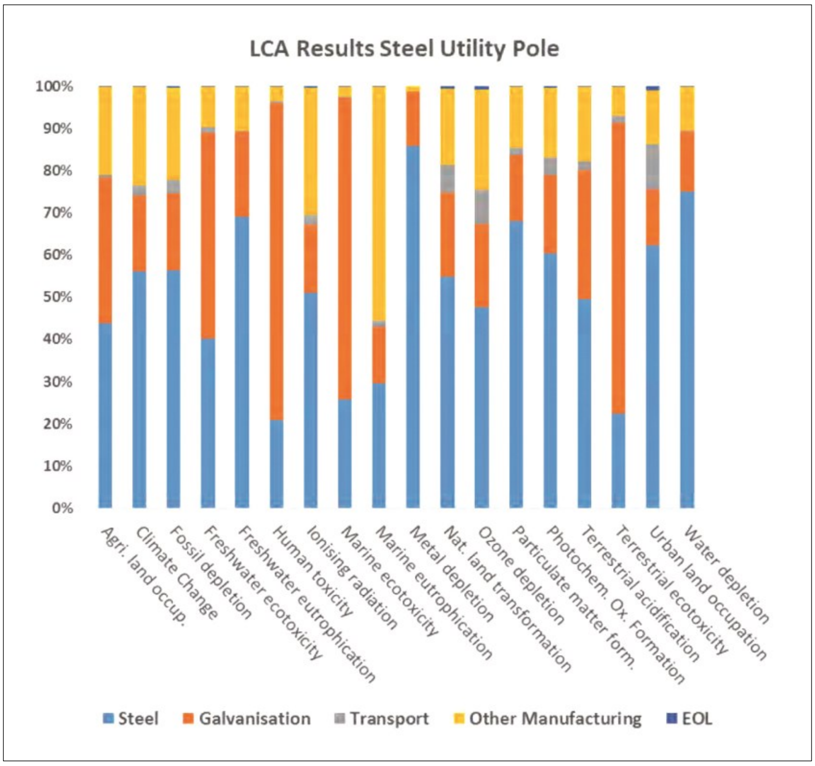
8.2.3. LCA comparison [17]

The LCA profile of steel poles is shown in graph 2.

As shown in this graph, the LCA impact of steel poles is strongly influenced by steel manufacturing. In addition, the cumulative toxicity to human health, land and water ecosystems is strongly influenced by the galvanization of the steel, which is necessary for environmentally and weather resistant poles.

[17] http://www.wei-ieo.eu/wp-content/uploads/2019/02/SEA-SM1_2016_FullReport.pdf

Graph 2. LCA profile of steel poles



Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

8.2.4. Examples of installation and use

In many countries, including where AFD operates, power grid managers have used steel poles in small quantities. Despite their advantages of being lightweight making them easier to install and strong, a deterrent to vandalism, steel poles are expensive and difficult to produce locally.

As examples, however, we note:

- Structa's (South Africa) use of steel poles **in mines** in the Democratic Republic of Congo (DRC) and Namibia.
- KEC International's installed steel poles **in downtown** N'Djamena (Chad).
- Fuchs Europoles (Germany) installed steel poles **in storm-prone areas** or due to **integration reasons in regional parks** in Germany and Switzerland on behalf of ED Netze.
- 6,000 steel poles installed by Structa (South Africa) for Eskom.

Metal poles (single-pole type) are now being considered for use in Tanzania and Nigeria to deal with the increasing damage to wood poles.

8.2.5. Producers

Steel poles production is rather concentrated among specialized producers, with well-tried industrial processes, in order to achieve lower costs. These producers are mainly located in industrial countries.

The main producers are:

- in the U.S.: Valmont (world leader).
- in the Middle East: Al-Bab, El-Sewedy.
- in India: KEC International.
- in China: Metal Utility Poles, Wuxiao (limited presence in the distribution market).
- in Europe: Fuchs Europoles (Germany).
- in South Africa: Structa.

In Morocco, the National Office of Electricity and Drinking Water (ONEE) has listed metal poles from more than ten national manufacturers, thus putting its trust in a network of local semi-industrial craftsmen (Emteyco - the Moroccan leader, Électro Tadart, Fabrilec, Funtan, Geemag, Lumafric, Sara électrique, Somodelco, Zamil) rather than the major international players.

This market structure is an exception and illustrates a replicable pattern in many countries, provided that the emergence of such a network of players is fostered over time by the government or local power grid managers.

8.3. Concrete

8.3.1. Physical properties

The manufacturing processes for concrete poles make it possible to have a variety of shapes and features. Concrete poles can be:

- solid or hollow.
- rectangular or H-shaped.
- cast or spun for greater strength.
- pre-stressed or simply reinforced.

Photo 3. Example of an aerated cast concrete pole

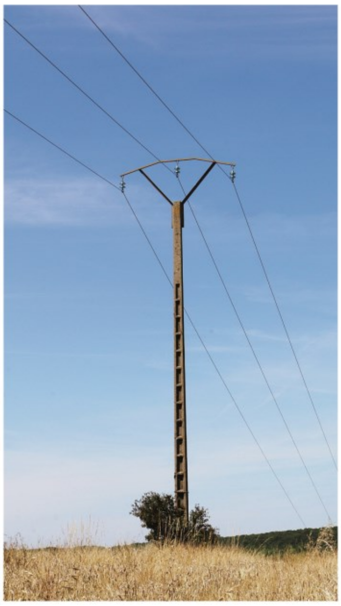


Photo 4. Example of a cylindrical sectioned concrete spun pole

Table 7. Weight comparison of concrete and wood poles

Pole height (m)	Type	Weight of wood pole (kg)	Weight of concrete pole (kg)
8	L	143	788
8	M	157	795
10	M	259	1,019
10	S	395	1,103
12	M	356	1,216
12	S	539	1,359
14	S	686	1,612
18	S	1,110	2,573

Source: based on data from SEA Full Report, WEI-IEO (Brussels), August 2016.

Furthermore, in 2021, ORNL uses a 12.5 meter high reference pole:

- a wood pole weighs 1,315 kg.
- a concrete pole weighs 3,793 kg.

This data is undisputed and the drawback of the weight of concrete poles is widely acknowledged.

8.3.2. Advantages and disadvantages of concrete poles

Concrete poles also have distinct advantages:

- they are fire resistant.
- they are resistant to insects.
- during use, they do not pose a danger to human health or the environment.
- their physical properties are stable.
- they require little maintenance.
- inspecting them is neither destructive nor invasive to the pole.
- they are fully recyclable as concrete aggregates.
- most of the time they can be repaired after an impact with a vehicle for example.
- it is easy to make holes in them for line brackets or any other accessory.
- their service life can reach 50 years.
- they withstand great stress.

On the other hand, like steel poles, concrete poles have some significant disadvantages:

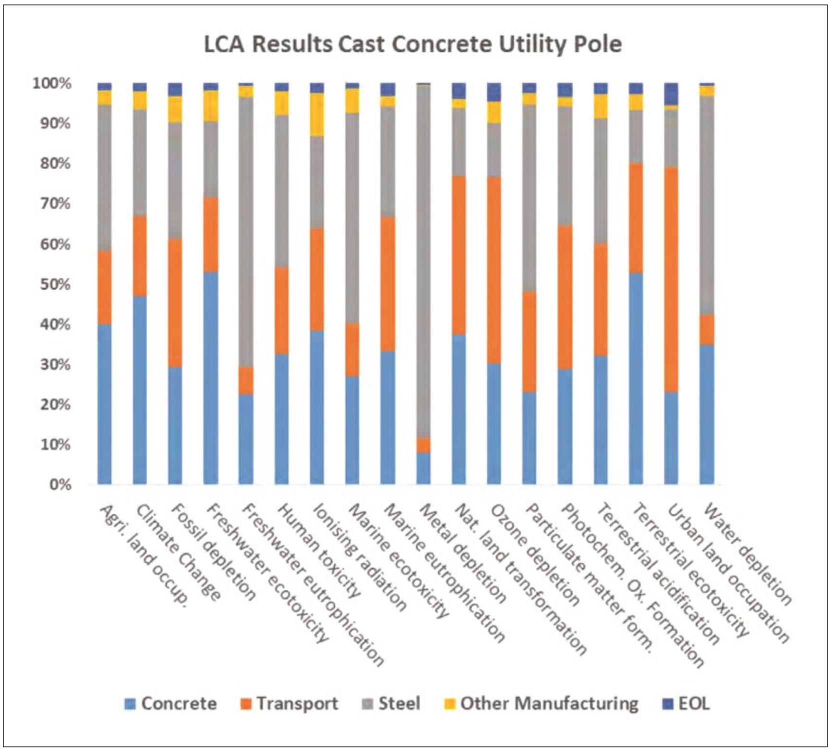
- they are less easily transported because they are much heavier. This can be prohibitive when shipping conditions are difficult.
- they have a worse carbon footprint than wood poles.
- their manufacture requires non-renewable resources and a lot of energy.
- they are more expensive than wood poles.
- the steel reinforcement may be subject to corrosion in acidic or saline atmospheres, if the post becomes cracked or damaged.

8.3.3. LCA comparison [18]

The LCA analysis of the cast concrete poles results in the following profile: in the case of cast concrete (graph 3), a large part of the LCA impact comes from the raw materials used (steel and cement) to which a strong sensitivity to shipping is added, underlining the impact of the weight of materials and poles and the distance, in some cases, from cement production sites.

[18] http://www.wei-ieo.eu/wp-content/uploads/2019/02/SEA-SM1_2016_FullReport.pdf

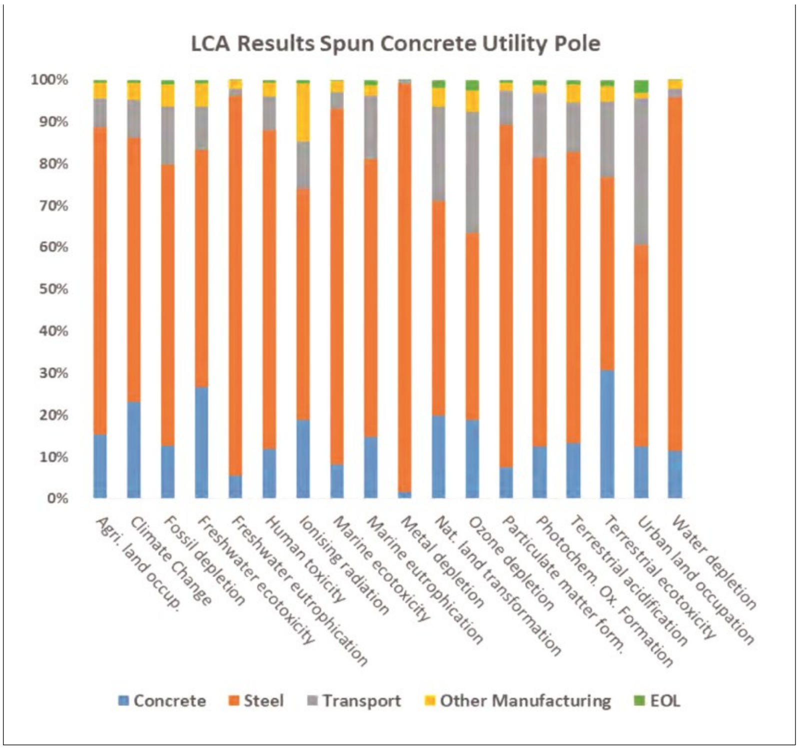
Graph 3. LCA profile of cast concrete poles



Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

Similarly, the LCA analysis of cast concrete spun poles results in the following profile:

Graph 4. LCA profile of cast concrete spun poles



Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

Graph 4 shows that the LCA impact of cast concrete spun poles comes primarily from the steel.

8.3.4. Examples of installation and use

There are examples of their use in many countries, including in the areas where AFD operates. Despite their drawbacks, concrete poles are a frequent alternative to wood poles when the latter pose too many constraints. They are even easier to install because concrete poles can be easily manufactured almost anywhere.

Concrete poles are used in Japan where they are a more satisfactory solution than wood poles due to the risk of **earthquakes**.

In Nigeria, concrete poles are now being used to deal with the **vandalism** of wood and metal poles.

8.3.5. Producers

Some countries, where concrete poles are dominant, have seen the emergence of a major manufacturer, a market leader (example: Nippon Concrete in Japan).

At the same time, some countries, where concrete poles are dominant, have seen the development of an industry made up of strong small and medium enterprises (SMEs) (examples: Electrobéton, OTEP, SIEBA, Stradal in France).

Emerging countries have a network of well-established manufacturers (examples: Atlas PDA, Atlas Poteaux, Brinell, Électricité Bellet, ENTEG, Mars Industrie, Presud, SAGAP, SEGMO, SGFE, Siwar, Zinco in Morocco).

Other emerging countries have recently developed, under the impetus of the government or the local energy company, a network of manufacturers able to meet emerging demand:

- CBD, CCCG, Law Brothers, Leader, SCCP and SET in Cameroon.
- Les Préfabriqués du Faso, PPI, SIMEEL, Sys Masten in Burkina Faso, with daily capacities ranging from 70 to 200 poles per plant.

Market players based in one country can serve neighboring markets such as Rocla in South Africa, which also serves Namibia and Botswana.

8.3.6. Local production

Once access to the necessary raw materials (sand, gravel, and cement) has been secured, setting up a concrete pole manufacturing plant does not pose any particular difficulty. Local manufacturing of concrete poles can therefore be easily arranged.

Few assets are needed. As an example, a manufacturing plant built in Benin to produce 24 Class A and 3 Class C poles per day requires:

- a storage area for 1,500 m^3 of gravel.
- a storage area for 1,500 m^3 of sand.

- a storage area for 400 tons of cement.
- two 600-liter concrete mixers.
- two 300-liter pourers each.
- a 3.5 ton bridge.
- 27 molds.
- a 1,500 m^2 storage area for finished poles.

It costs between 10 and 12 million EUR to build this type of manufacturing plant.

8.4. Composite materials

Many composite materials are used for utility poles: in general, a composite material is a mixture of materials whose properties (especially mechanical strength and rigidity) are better than those of each of its components. It can be a mixture of metals or materials reinforced with glass or carbon fiber.

As far as utility poles are concerned, they are mostly fiber reinforced polymers. These poles are relatively new since the first one was installed in 1993.

8.4.1. Physical properties

The physical properties obviously depend on the type of composite materials. However, there are some common characteristics that are apparent.

In general, the stiffness-to-weight ratio is much higher than that of other materials. In terms of weight alone, composite poles are lighter than wood poles.

Table 8. Weight comparison of composite and wood poles

Pole height (m)	Type	Weight of wood pole (kg)	Weight of steel pole (kg)
8	L	143	117
8	M	157	-
10	M	259	213
10	S	395	298
12	M	356	281
12	S	539	402
14	S	686	524
18	S	1,110	-

Source: based on data from the SEA Full Report, WEI-IEO (Brussels), August 2016.

8.4.2. Advantages and disadvantages of composite poles

The main advantages of composite poles are:

- they are fire resistant with a protective coating.
- they are resistant to insects.
- during use, they do not pose a danger to human health or the environment.
- their physical properties are very stable.
- they are virtually maintenance free.
- most of the time they can be repaired after an impact with a vehicle for example.
- it is easy to make holes in them for line brackets or any other accessory.
- although there is not enough time to accurately estimate this, it is reasonable to expect that their service life will exceed 70 years.
- they can be easily transported and installed because they are lighter than other poles.

On the other hand, they have some significant drawbacks:

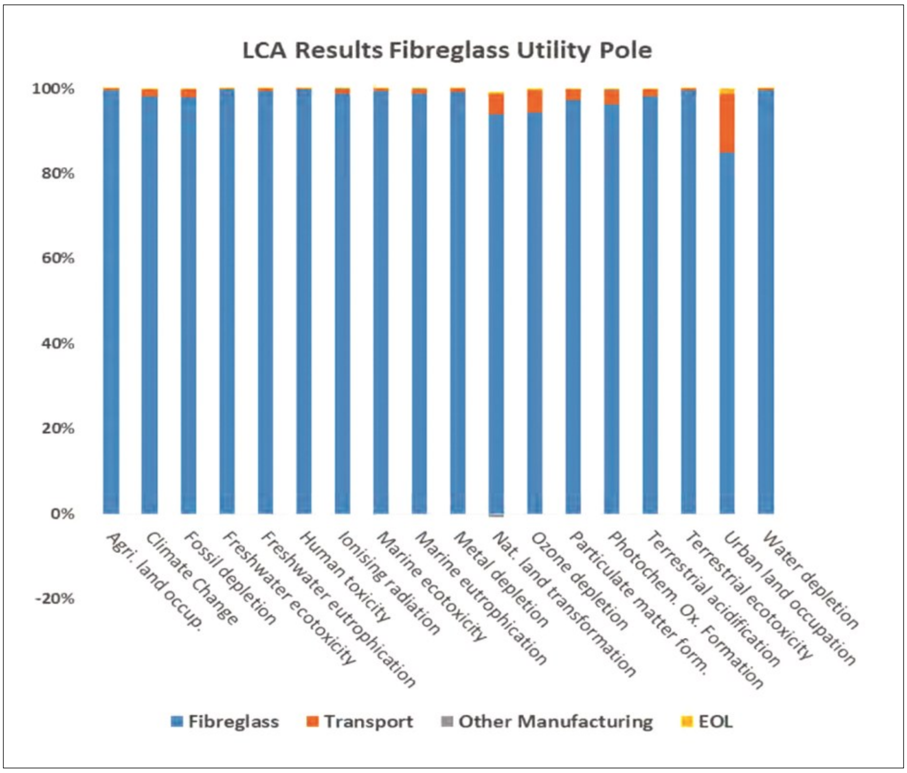
- they are much more expensive than other poles.
- depending on the composite materials, recycling can be tricky and the shredded material is poorly reused.

8.4.3. LCA comparison [19]

The profile resulting from the LCA of high fiberglass content composite poles is shown in graph 5; the graph shows that almost all of the LCA impact of poles made of composite materials comes from the manufacture of the fiberglass.

[19] http://www.wei-ieo.eu/wp-content/uploads/2019/02/SEA-SM1_2016_FullReport.pdf

Graph 5. LCA profile of composite poles



Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

8.4.4. Examples of installation and use

Composite poles have been used:

- in **highly hurricane-prone** areas, requiring very strong poles (Southern California Edison).
- in **drinking water collection** areas as with E.ON in Sweden.
- in remote areas, requiring the **poles to be transported by helicopter** as in Norway with Mørenett.

The main implementations are in niche situations, in developed countries, perhaps less sensitive to the cost of these poles.

8.4.5. Producers

The production of these poles remains and will remain for a long time a specialized business. Given the limited market penetration of this technology, producers are located in industrialized countries, mainly in the USA, and export their production. The main producers of composite poles are Duratel, Strongwell, Shakespeare (Valmont subsidiary), PUPI, and Jerol.

8.5. Pole lining

Wood poles installed in wetlands deteriorate faster in the underground part, while the open air part is less prone to mold.

Solutions have been developed to prolong the life of the poles by protecting the buried part.

The Polesaver® solution is a thermoplastic sheath surrounding the base of the pole, making it possible for its manufacturer to claim a gain in life expectancy of 20 years, for an additional cost of around 1 to 2% of the cost of replacing a pole.

The Polesaver® sleeve has sold 7 million units since 1994 and is now routinely applied by UKPN to these wood poles.

In Germany, Fürstenberg's Permadur® solution uses the same principle by wrapping the base of the pole with a metal sheet in a shrink sleeve.

These solutions are of little value in areas where the life expectancy of wood poles exceeds 50 to 60 years, but can be critical in areas that are less favorable to wood poles.

9. COMPARATIVE LCA OF VARIOUS SOLUTIONS

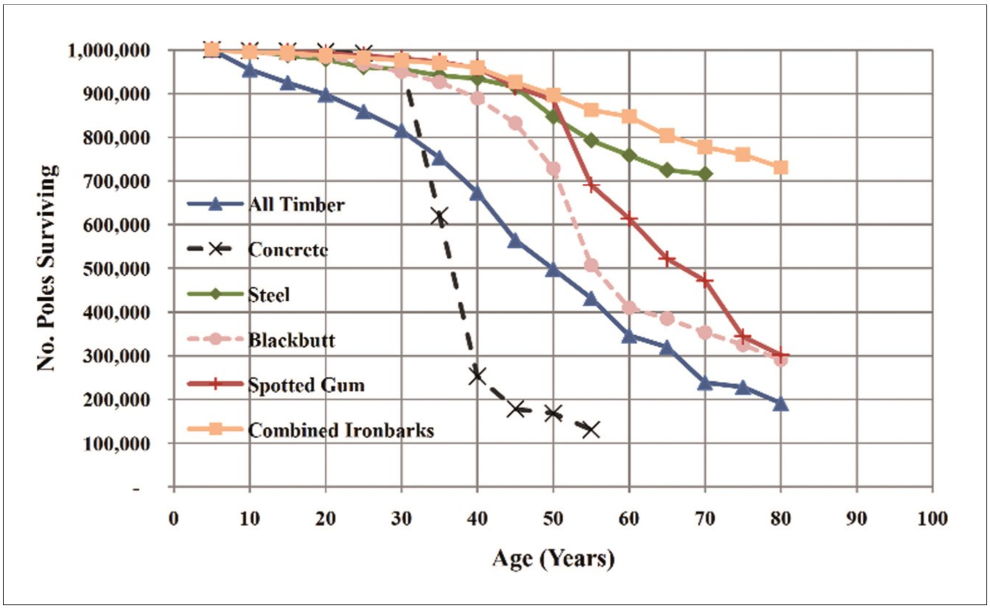
Several LCAs have been conducted to compare the performance of various pole types. Most of the freely available LCAs have been commissioned to validate a technology and make a case for that technology. The most frequent sponsors of these studies are the steel and wood preservation trade associations and certain manufacturers.

The results should therefore be taken with a degree of caution. I mention below some studies whose results seem to be confirmed by "neutral" studies, e.g. conducted by university teams.

9.1. Service life of poles

A study conducted in Australia illustrates how poles age and how their service life is based on the materials they are made of [20].

Graph 6. Speed poles age depending on the materials they are made of



Source: Nathan Spencer & Leith Elder, Pole Service Life – An Analysis of Country Energy Data.

In Australia, the service life of concrete poles is approximately 35-40 years. This service life can be affected by the country's weather conditions. In all countries, an average service life of 40 to 50 years is acceptable.

[20] Pole Service Life – An analysis of Country Energy Data (Australia), Nathan Spenser Koppers Wood Products, Sydney, Australia.

The service life of steel poles is longer. It also depends on atmospheric conditions (humidity, salinity…). For more than 70% of the poles, the service life is over 70 years but for 5% of the poles, which are more exposed, it does not exceed 40 years. An average service life of 60 years under favorable conditions is therefore acceptable.

When it comes to wood poles, there are many types of stresses and their service life varies greatly. For 5% of them, it is less than 10 years. In this case, replacing them with concrete, steel, or composite poles is necessary. But for 20% of the wood poles, probably in a very dry atmosphere, the service life exceeds 80 years. An average service life only makes sense for a country and relatively homogeneous conditions: in Sweden, the lifespan taken into account by the power grid managers is 60 years. In equatorial environments, it is only a maximum of 20 to 30 years.

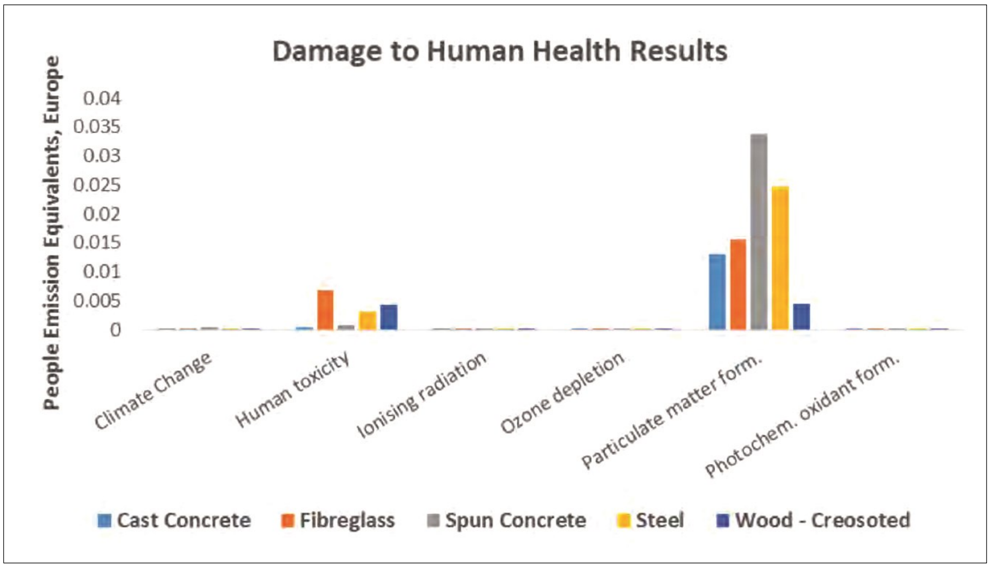
9.2. LCA CONDUCTED BY WEI-IEO [21]

WEI-IEO is a European trade association representing the wood treatment industry. With the title "*Treated wood: a sustainable choice*" on its website, the WEI-IEO clearly states its position. The LCA conducted by the WEI-IEO has therefore some reasons to subscribe to this position.

The main basic assumptions are balanced: the service life of the poles is 80 years for steel (quite advantageous), 60 years for concrete, 50 years for treated wood (valid for Europe) and finally 80 years for composite materials.

The LCA excludes the benefits of potentially producing energy by incinerating creosote-treated wood, which could have been a factor in their favor.

Graph 7. WEI-IEO LCA: human health impacts



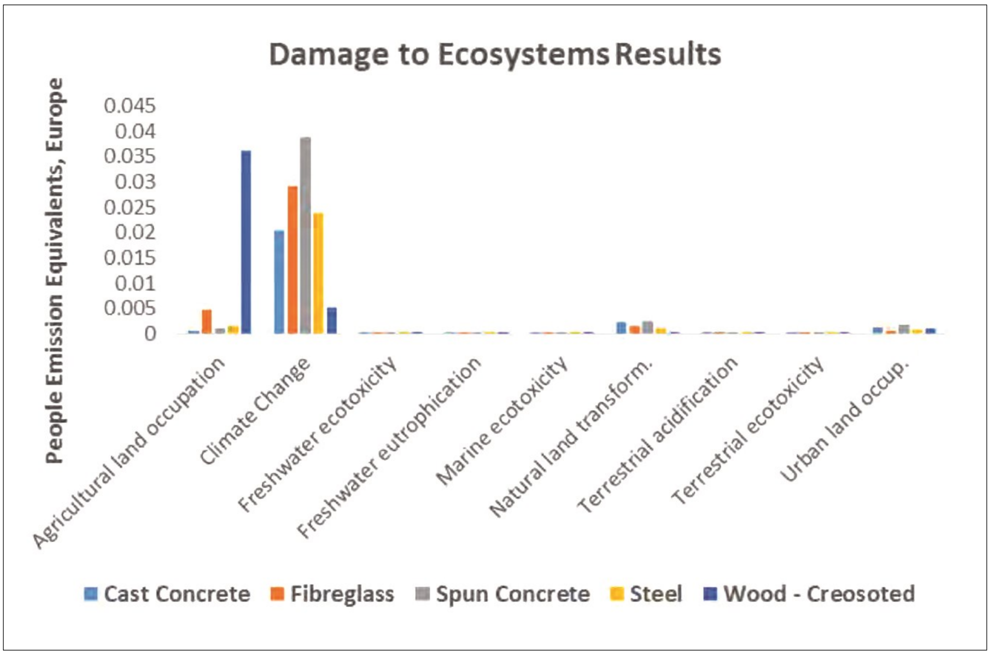
Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

[21] http://www.wei-ieo.eu/wp-content/uploads/2019/02/SEA-SM1_2016_FullReport.pdf

The human health impact of the composite poles is due to the arsenic, antimony, and cadmium emissions generated while the fiberglass is being manufactured. The impact of wood poles is also significant.

Unfortunately, in the mechanics of an LCA, the relative weight of the "human toxicity" criterion remains limited and does not reflect the reasons that may simultaneously lead to banning a wood treatment product.

Graph 8. WEI-IEO LCA: environmental impacts



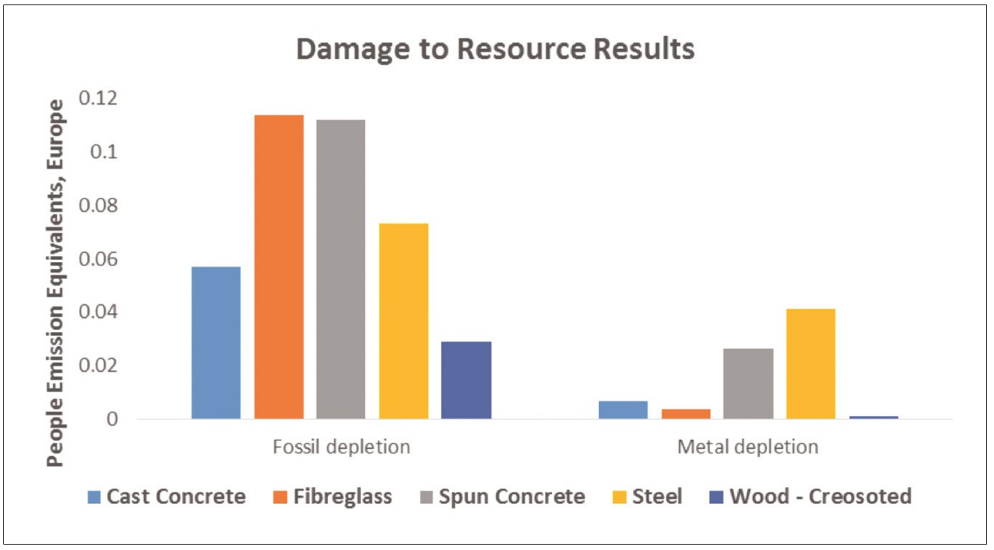
Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

The most visible impacts involve CO_2 emissions which wood poles contribute the least to. For the other impacts, the extraction of the raw materials and the manufacturing of the base materials (steel, cement, and fiberglass) produce a high rate of emissions.

This result clearly pits a more limited impact of wood poles on CO_2 emissions against a significant impact on health and ecosystems due to the preservatives used.

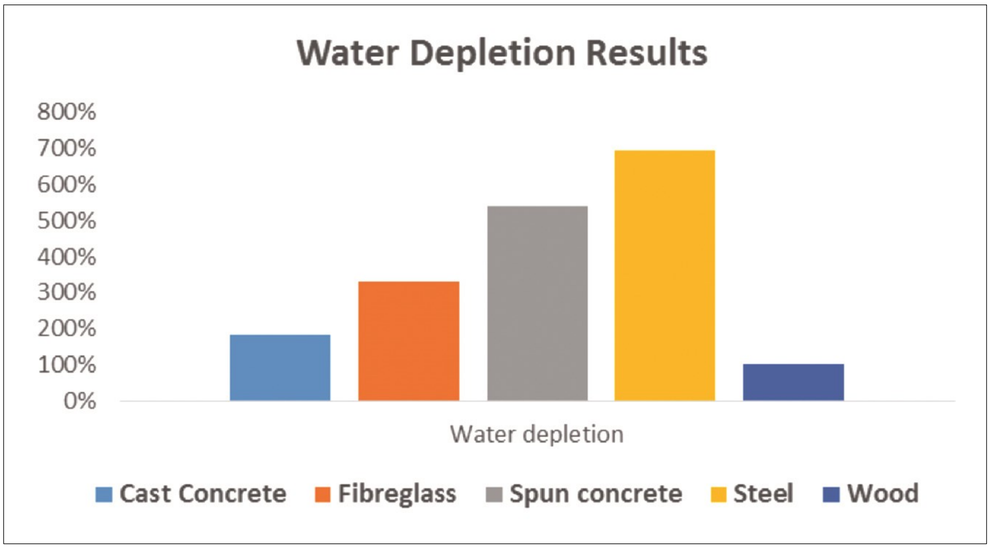
The benefit on CO_2 emissions is the basis for proponents of the treated wood industry's argument.

Graph 9. WEI-IEO LCA: impacts on resource consumption



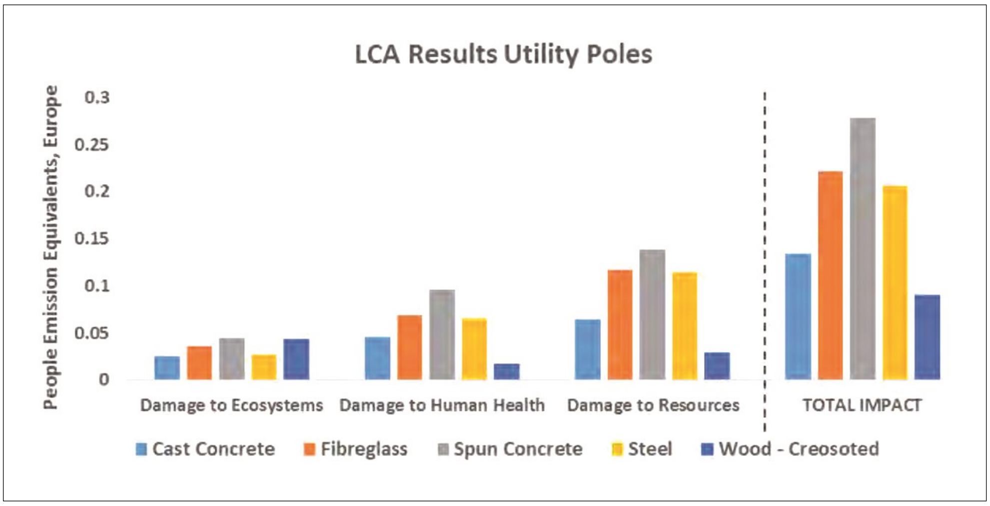
Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

Graph 10. WEI-IEO LCA: impacts on water consumption



Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

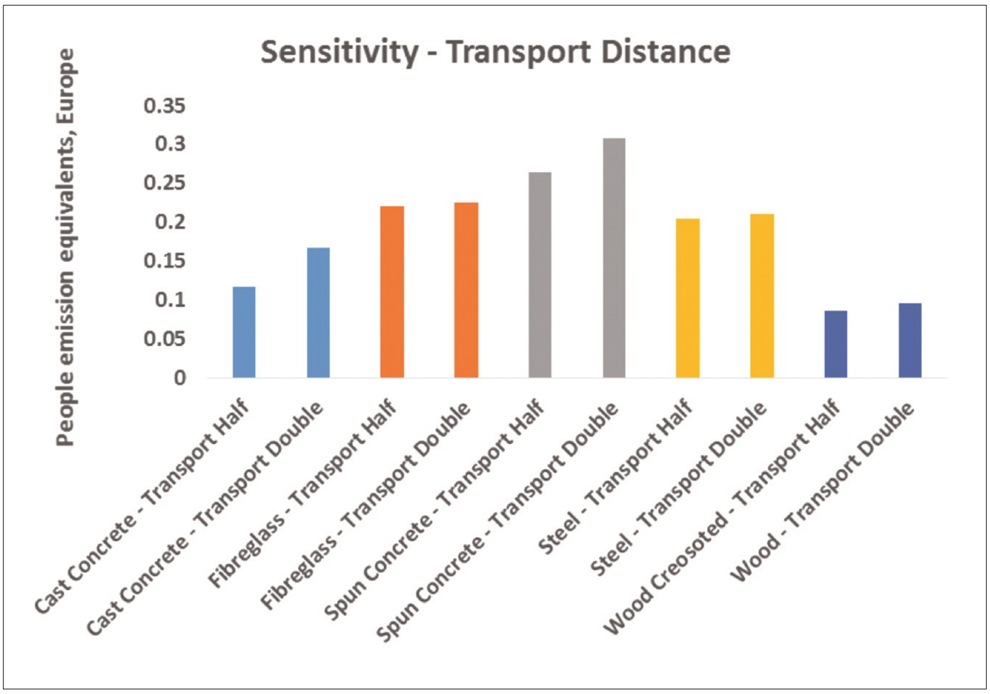
Graph 11. WEI-IEO LCA: global impact



Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

The global impact, a weighted indicator providing a summary of all the impacts reviewed above, shows a clear advantage for creosote-treated wood. However, one should be careful, as this result is strongly dependent on the relative weight given to each criterion. According to this Australian study, creosote-treated wood poles have a lower impact on human health which would then lead to the conclusion that it is the best solution, yet creosote is now banned in Europe because of the health hazards it poses.

Graph 12. WEI LCA: sensitivity of the overall results for shipping



Source: Socioeconomic Analysis (SEA) of Creosoted Wood Pole Applications (Full Report), WEI-IEO (Brussels), August 2016.

Graph 12 shows the interest in creating local industrial channels for concrete poles as soon as significant quantities are involved.

9.3. LCA CONDUCTED IN 2012 BY THE TREATED WOOD COUNCIL (TWC)[22]

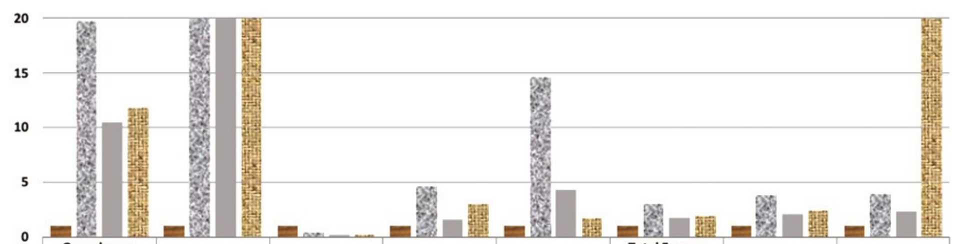
Another LCA, conducted in 2012 in the U.S. context where lobbying by the wood treatment industry is very strong, confirms the previous findings.

The environmental impact of manufacturing the steel, cement, or composite materials needed to make the poles is greater than the impact of wood poles over their life cycle.

Even without taking into account the lifetime carbon capture of the trees used to make poles, the CO_2 emissions associated with wood poles are much lower than the emissions generated by other types of poles.

Although conducted by an association defending the interests of the wood industry like the previous study, the main conclusions of this study are now universally shared. However, it may be possible to discuss the extent of the advantage that wood solutions have on certain criteria?

Graph 13. Treated Wood Council (TWC) LCA: environmental impacts of various types of poles



	Greenhouse Gas	Acid Rain	Smog	Eutrophication	Ecotoxicity	Total Energy Input	Fossil Fuel Use	Water Use
Pentachlorophenol-treated	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Concrete	20	77	0.40	4.7	15	3.0	3.8	3.9
Galvanized steel	11	54	0.18	1.5	4.3	1.7	2.0	2.3
Fiber-reinforced composite	12	38	0.15	3.0	1.7	1.9	2.4	27

Notes: Some acid rain and water use values exceed the presented vertical scale of this graphic. Total greenhouse gas is not shown because of negative values for pentachlorophenol-treated poles.

Source: Conclusions and Summary Report on an Environmental Life Cycle Assessment of Utility Poles ©Treated Wood Council (March 2012).

[22] https://members.southernpine.com/publications/download/52d003da53eb9ac97a00008e/LCA_UTILITYpoles_March2012.pdf

Table 9. Treated Wood Council (TWC) LCA: environmental impacts of various types of poles (continued)

Impact category	Units	Pentachlorophenol -treated pole	Concrete pole	Galvanized steel pole	Fiber-reinforced composite pole
Energy use					
Energy input (technosphere)	MMBTU	4.0	6.5	2.9	0.19
Energy input (nature)	MMBTU	1.5	10	6.5	11
Biomass energy	MMBTU	1.5	0.094	0.11	-0.012
Environmental indicators					
Anthropogenic greenhouse gas	lb-CO_2-eq	162	3,190	1,699	1,911
Total greenhouse gas	lb-CO_2-eq	-789	3,213	1,725	1,908
Acid rain air emissions	lb-H+ mole-eq	11	886	622	436
Smog potential	g NOx / m	13	5.0	2.3	1.9
Ecotoxicity air emissions	lb-2,4-D-eq	1.3	19	5.5	2.1
Eutrophication air emissions	lb-N-eq	0.068	0.32	0.10	0.20
Resource use					
Fossil fuel use	MMBTU	4.1	16	8.4	10
Water use	gal	46	180	106	1,248

Source: Conclusions and Summary Report on an Environmental Life Cycle Assessment of Utility Poles ©Treated Wood Council (March 2012).

9.4. LCA conducted in 2009 and 2012 by Martin Erlandsson [23]

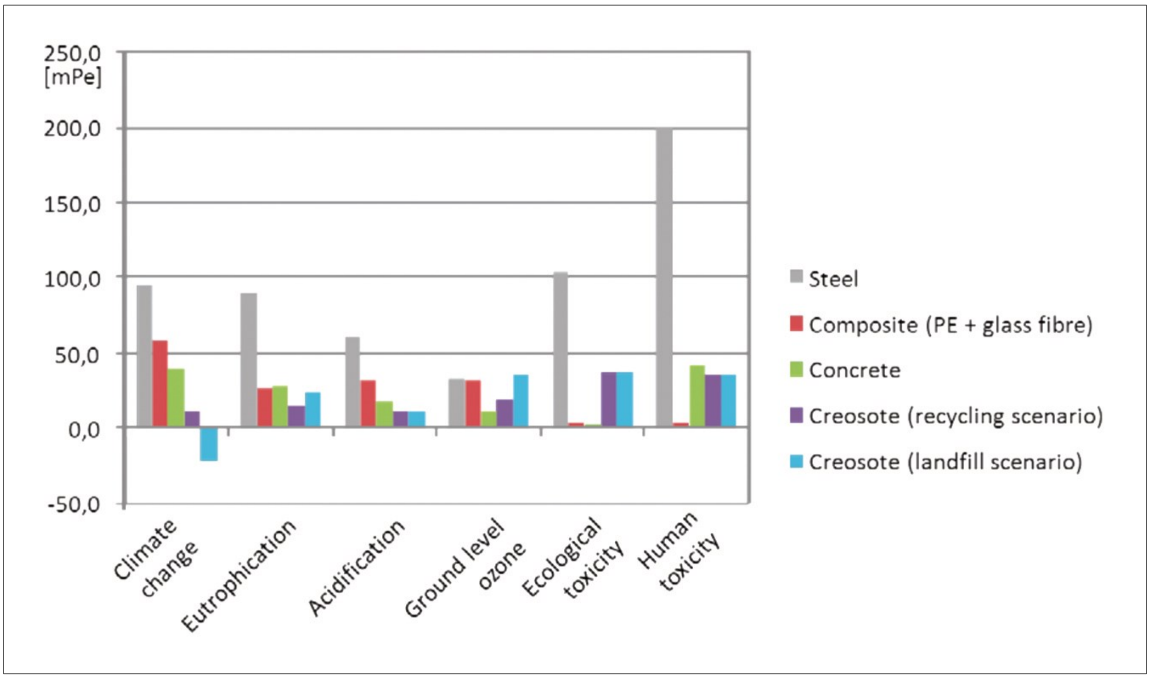
A first LCA had been conducted in Sweden by Martin Erlandsson in 2009 and completed in 2012. Even if it was based on debatable hypotheses (50 years of identical service life for all types of poles, presumption of recycling of all poles at the end of their useful life), it already concluded that wood poles had a lower environmental impact.

Of course, once again, these conclusions depend on the weight assigned to each criterion. The ban on hazardous materials such as creosote is not evident from the LCA results.

Nowadays, more and more wood treatment substances are banned or have strong restrictions on their use. This trend has every reason to continue. In Europe, the strong regulatory constraints have led the industry to look for new wood treatment solutions which, more or less, make it possible for wood poles to retain the advantages pointed out by the first LCAs.

[23] https://jerol.se/wp-content/uploads/2015/05/M_Erlandsson_IVL_B2004_EN.pdf

Graph 14. Martin Erlandsson's LCA:
environmental impacts of various pole types



Source: Martin Erlandsson (2011), Comparison of the environmental impacts
from utility poles of different materials – a life cycle assessment, IVL Swedish Environmental Research Institute.

Table 10. Martin Erlandsson's LCA:
environmental and health impacts of various types of poles

		Climate change	Eutro-phication	Acidi-fication	Photoch. ozone formation	Eco-toxicity	Human toxicity - USES LCA 1.0	Human toxicity - USEtox *	Energy ware consump., renewable	Energy ware consump., fossil
Type of result		LCIA [mPe]						LCIA [Pe]	LCI [MJ]	
Steel pole	Production	91	86	58	31	3,6	112	1 500	197	6992
	Service life	2,2	3,1	2,1	1,4	100	86,8	258 000	2	163
	End of life	1,2	1,6	1,1	0,7	<0,0	0,3	1,4	5	94
Composite pole	Production	57	19,5	31	31,2	3,2	3,9	33	133	4314
	Service life	0,4	0,5	0,3	0,2	<0,0	0,1	0,8	1,3	30
	End of life	0,2	0,2	0,1	0,1	<0,0	0,1	0,4	0,2	14
Concrete pole	Production	34	20	13	7,6	1,0	39,0	371	87	1457
	Service life	3,1	4,6	2,9	1,9	0,1	0,8	3,4	2	225
	End of life	0,8	1,3	0,8	0,6	<0,0	0,2	0,7	7	71
Creosote pole, recycling for energy recovery	Production	9,2	11,7	9,9	18	<0,0	2,5	7,1	2522	1743
	Service life	0,9	1,3	0,9	0,6	37	33	3,4	0,7	67
	End of life	0,8	1,4	0,9	0,7	<0,0	0,2	0,6	-2394	51
Creosote pole, landfill	Production	9,2	12	9,9	18	<0,0	2,5	7,1	2522	1743
	Service life	0,9	12	0,9	18	37	33	3,4	0,7	67
	End of life	-32	0,6	0,4	0,6	<0,0	0,1	0,5	0,3	32

**Values recalculated via 1,4-DCB eq.*

Source: Martin Erlandsson (2011), Comparison of the environmental impacts
from utility poles of different materials – a life cycle assessment, IVL Swedish Environmental Research Institute.

10. Comparing prices between technologies

Several sources (Preserved Wood, Michigan Tech [24], Creosote Council) agree that wood poles have the lowest ex-factory price, while steel poles cost more (+25% or so) and fiberglass poles cost three times more.

When transportation costs are added, steel poles are more expensive and, when delivered to the installation site, they cost between 70 and 100% more than wood poles. Concrete poles cost twice as much as wood poles and fiberglass poles cost 2.5 times as much.

A paper [25] presented at CIRED [26] 2011 gives slightly different ratios:

- cast concrete spun poles cost twice as much as wood poles, cast concrete about the same as wood poles; while steel poles cost four times as much as wood poles.
- but a TCO approach [27] (i.e. including end-of-life costs) gives a slight advantage to cast concrete spun poles over wood poles; finally, cast concrete poles cost about 20% more and steel poles three times more.

The TCO approach is not widely used, but it provides a more complete picture of the economic commitment made when choosing a pole technology.

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[24] https://www.researchgate.net/publication/304089802_Age-Dependent_Fragility_and_Life-Cycle_Cost_Analysis_of_Timber_and_Steel_Distribution_Poles_Subjected_to_Hurricanes

[25] http://www.cired.net/publications/cired2011/part1/papers/CIRED2011_0392_final.pdf

[26] International Center for Rechearch on Environment and Development.

[27] Total Cost of Ownership.

11. Evolution of some market examples

Originally, all electric utility poles were made of wood. It is interesting to note that some countries have not sought to innovate and continue to use the same type of poles with, in some cases, an industry that is reluctant to use other technologies in this area, while other countries have diversified the types of poles used in their power grids.

11.1. Long-established markets with a full mix

11.1.1. In Morocco

Morocco launched its electrification program in 1996.

Over the past 25 years, the National Electricity Board (NEB) has built a power grid using wood poles, steel poles, and concrete poles.

NEB has been able to identify and expand a network of local manufacturers for each of these technologies.

For wood poles, manufacturers (including Amida, Atlasien de traitement de bois - ATB, FBI, Poteaux bois Maroc, SIRA) treat the poles with creosote or CCA (a mixture of copper, chromium, and arsenic).

Steel poles (for transmission lines) are manufactured by specialized workshops including Emteyco, Electro Tadart, Fabrilec, Funtan, Geemag, Lumafric, Sara électrique, Somodelco, and Zamil.

Cement poles are manufactured throughout the country by a dozen manufacturers, including Atlas PDA, Atlas Poteaux, Brinell, Électricité Bellet, ENTEG, Mars Industrie, Présud, SAGAP, SEGMO, SGFE, Siwar, and Zinco.

Morocco's example shows that a complete mix of technologies can be developed in a short time, if necessary, relying mainly on local manufacturers.

11.1.2. In France

In France, 70% of utility poles are made of concrete and 30% are made of wood (the oldest ones have been treated with creosote, the most recent ones with CCA). Enedis, the main player in the market, relies on a network of manufacturers that have been established for many years in France and in neighboring countries (Belgium, for example).

Given the size of the French market, Enedis' industrial suppliers have become large enough to expand their export business.

Rondino and the leading supplier of wooden poles, France Bois Imprégnés (MOULINVEST group), both have several production sites.

The cement poles are manufactured by Électrobéton, OTEP, SIBA, and Stradal.

11.2. Stronger wood pole markets

These markets are located in countries that produce wood and therefore treated wood poles. They have therefore created a comprehensive wood industry, part of which is threatened by the new regulations on wood treatment products.

Naturally, the wood industry is strongly defending itself in these countries so as not to lose its dominant position.

The main world market is the **United States**, which is the epitome of this category.

To a lesser degree, **South Africa** is included in this group of markets. The country has long developed a local manufacturing of wood poles that has supplied all the neighboring countries (Namibia, Zimbabwe, Botswana, Mozambique, and Malawi), exporting its production to East Africa (Kenya and Tanzania). This area of influence is tending to shrink due to countries seeking to reduce their reliance on foreign suppliers.

There are many wood pole producers, organized in small production units, organized in a strong, active association. The leader among them is Treated Timber Products.

Although the South African market is dominated by wood poles, other manufacturers have expanded to provide steel (Sectional Poles), concrete (Rocla), or composite (Saltus) poles. However, it does not have the characteristics of a full mix market.

Having once had South Africa as its main supplier, **Tanzania** banned treated wood poles from Uganda, South Africa, and Zimbabwe in 2016. This decision has greatly boosted the development of local producers. The number of local producers has increased from two in 2015 to eleven in 2021. The older ones treated the wood with CCA and creosote was allowed as of 2017.

Given the deterioration of the poles, Tanesco, the local power grid manager, has been evaluating the possibility of using cement poles since 2020. In response to the threat of this shift in pole technology, the wood industry protested in 2020. At the same time, concrete pole manufacturers like TCPM and Everwell are growing rapidly.

11.3. Wood pole markets in a state of change or in need of change

Other markets were historically dominated by wood poles until recently. For a variety of reasons, including high operating costs, difficulty in obtaining raw materials, deterioration and vandalism, they have had to initiate a shift and switch to a different technology for a large proportion of their utility poles installed.

In these situations, concrete poles are generally the most frequently chosen alternative, as they can be easily produced locally: this is the case in countries such as **Cameroon** or **Burkina Faso**.

11.4. Wood pole markets with no prospect of change in the immediate future

Dry, desert areas have a climate and soil that are not very harsh on utility poles. Wood-eating insects do not necessarily thrive there. Although they do not have access to the raw materials (wood), these countries have no reason to change technologies and continue to use wood poles as the cheapest solution for purchase. In the most extreme cases of drought, the use of untreated poles can be considered and explored.

Depending on the market, the eventual ban of a wood treatment substance, enacted in the wake of global regulatory developments, will in most cases result in the local treated wood industry adapting to the use of new substances. This impact will be minor as changing wood preservatives does not require significant changes in impregnation processes. Each manufacturer will therefore be able to adapt quickly.

12. Summary table

The choice of technology for electric utility poles is first of all a question between:

- **economic or CO_2 emission reduction goals** in favor of treated wood poles.
- **or human health and environmental protection goals** in favor of steel, wood, or composite material poles.

For a power grid manager, it makes little sense to prioritize a single technology. Each technology has advantages and disadvantages depending on the location of the power poles, which may **influence a general preference** between savings and CO_2 emissions on the one hand, and impacts on human health and the environment on the other.

The main influencing factors include:

- in areas where transportation is difficult, sandy or muddy roads, cement poles are not recommended, steel poles require special precautions; also, wood poles can be selected as a solution.
- in very dry climates, the economic advantage of wood poles is increased because they have a longer life span.
- in very wet climates, the advantage of wood poles is reduced.
- in the case of wood poles installed in wet soils, a liner is recommended or even mandatory to extend the life of the poles.

Steel, concrete, or composite poles are more weather-resistant:

- in areas of high fire risk, cement, steel, or composite poles are preferable.
- in areas subject to very heavy storms, cement, steel, or composite poles are also preferable.
- in areas subject to frequent flooding, cement, steel, or composite poles are again preferable.
- in urban areas, where the proximity between people and poles is greater, cement, steel, or composite poles are also preferable.
- in areas where damage to poles is significant (vandalism, theft of materials), cement or composite poles are preferable.
- if local manufacturing of poles is desired, wood or cement poles should be preferred.

Table 11 provides an overall comparison of the solutions available.

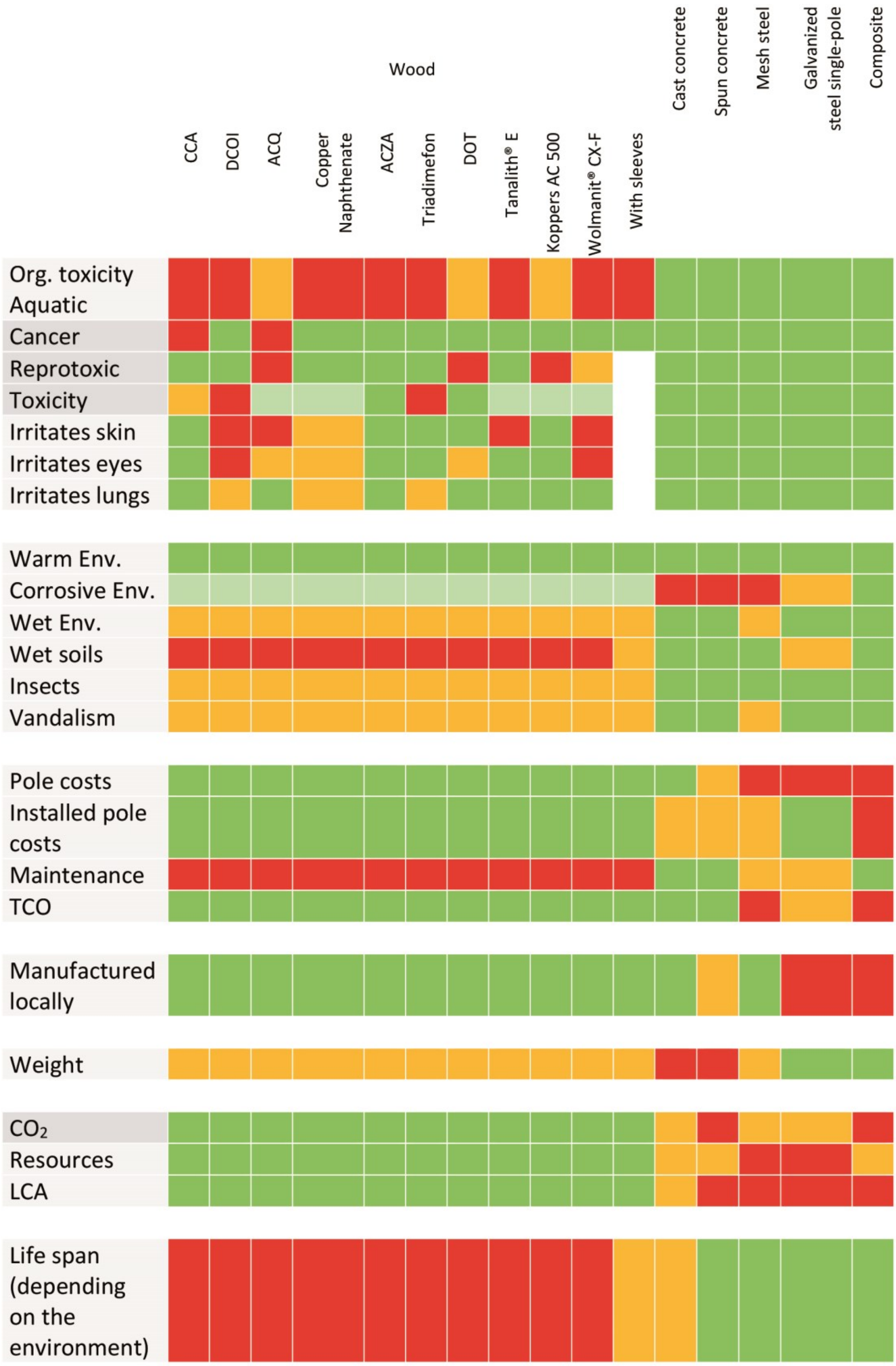
The color code ranges from green (favorable, suitable solution) to red (problematic, unsuitable or even to be avoided).

The table clearly shows that wood poles pose toxicity and adaptation issues in certain environments, while the other solutions have limitations in terms of cost and LCA criteria, including CO_2 emissions over the life span of the poles.

Some criteria are dependent, which the table does not show. For example, the service life of wood poles is shorter overall than that of steel or concrete poles, but this is not true in the specific case of a very dry desert environment.

This table thus makes it possible to guide us to the best (or least problematic) choice according to (i) environmental and human health protection needs, (ii) the environments in which the poles are to be installed, (iii) the economic constraints to be adhered to, or (iv) the local production requirements.

Table 11. Summary Table



Source: compiled from ECHA data - http://echa.europa.eu (2022) for columns 1 to 11, and diffuse data for columns 12 to 16.

Appendix. Estimating the number of power poles in each country

A study conducted by the University of Applied Sciences in Vienna (Austria) has shown a strong correlation between the length of a power grid and the energy supplied and the number of households served.

Number of km of lines =
0.03535 x number of households served + 1,459.19 x number of TWh supplied

Considering an average distance of 75 meters between two poles, the estimated number of power poles in each country is shown in the table below: (source: Küfeoğlu S., M. Pollitt & K. Anaya, Electric Power Distribution in the World: Today and Tomorrow, University of Cambridge, Energy Policy Research Group, EPRG Working Paper 1826, August 2018).

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
Afghanistan	98.7%	4,092, 477	6,023	153,457	2.05
South Africa	91.2%	17,733,119	210,304	933,739	12.45
Albania	100%	862,512	4,849	37,565	0.50
Algeria	100%		62,062	90,560	1.21
Germany	100%	40,624,971	524,268	2,201,099	29.35
Angola	43.3%	6,463,847	10,364	243,620	3.25
Saudi Arabia	100%		322,372	470,401	6.,27
Argentina	100%	13,925,275	125,030	674,700	9.00
Armenia	100%	837,896	5,791	38,069	0.51
Aruba	100%	38,855	899	2,685	0.04
Australia	100%	10,220,186	241,020	712,977	9.51
Austria	100%	3,933,516	66,849	236,595	3.15
Azerbaijan	100%	2,217,398	20,286	107,986	1.44
Bahamas	100%	114,679	1,770	6,636	0.09
Bahrain	100%		27,447	40,050	0.53

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
Bangladesh	100%	37,957,746	70,594	1,444,816	19.26
Belarus	100%	3,789,941	32,736	181,742	2.42
Belgium	100%	4,883,743	82,051	292,368	3.90
Belize	99,5%		568	828	0.01
Benin	41.5 %	2,335 ,719	1,188	84,301	1.12
Bermuda	100%	28,314	560	1,818	0.02
Bhutan	100%		2,386	3,481	0.05
Bolivia	95.6%	3,295,144	9,057	129,699	1.73
Bosnia-Herzegovina	100%		12,253	17,879	0.24
Botswana	64.9%	67,386	3,301	7,198	0.10
Brazil	100%	64,124,398	597,234	3,138,275	41.84
Brunei	100%		3,555	5,187	0.07
Bulgaria	100%	2,973,737	33,134	153,470	2.05
Burkina Faso	14.4%	3,630,745	1,760	130,915	1.75
Burundi	11%	2,548,469	339	90,583	1.21
Cambodia	91.6%	3,315,050	8,402	129,447	1.73
Cameroon	62.7%	4,877,120	6,743	182,245	2.43
Canada	100%	15,618,491	549,263	1,353,592	18.05
Chile	100%	5,440,715	74,992	301,756	4.02
China	100%	522,689,264	8,312,800	30,607,020	408.09
Cyprus	100%	318,823	4,524	17,871	0.24
Colombia	99.9%	14,282,545	70,203	607,327	8.10
Comoros	81.9%	141,171	93	5,126	0.07

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
North Korea	48.5%	6,502,416	12,708	248,403	3.31
South Korea	100%	20,495,634	527,035	1,493,564	19.91
Costa Rica	100%	1,476,628	10,065	66,885	0.89
Ivory Coast	67.0%	5,197,095	6,686	193,473	2.58
Croatia	100%	1,451,732	17,475	76,818	1.02
Cuba	100%	3,568,550	16,341	149,992	2.00
Denmark	100%		32,703	47,719	0.64
Djibouti	60.4%		381	555	0.01
Dominique	100%		59	86	0.00
Egypt	100%	24,496,076	150,579	1,085,659	14.48
El Salvador	100%	1,662,356	6,212	67,828	0.90
United Arab Emirates	100%		119,455	174,307	2.32
Ecuador	100%	4,659,382	24,605	200,612	2.67
Eritrea	49.6%		408	595	0.01
Spain	100%	17,565,288	241,563	973,419	12.98
Estonia	100%	57,844	8,858	14,970	0.20
United States	100%	132,736,055	3,989,566	10,513,754	140.18
Ethiopia	45%	21,850,103	8,986	785,513	10.47
Fiji Islands	99,6%	194,497	997	8,330	0.11
Finland	100%	2,652,262	84,207	216,631	2.89
France	100%	30,217,950	449,422	1,723,996	22.99
Gabon	93%	53,123	2,230	5,131	0.07

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
Gambia	60.3%	28,379	291	1,427	0.02
Georgia	100%	1,113,542	12,179	57,135	0.76
Ghana	82.4%	8,862,356	8,842	326,186	4.35
Gibraltar	100%		196	286	0.00
Greece	100%	4,394,506	53,635	233,609	3.11
Grenada	95.3%		198	288	0.00
Greenland	100%		496	723	0.01
Guam	100%		1,639	2,391	0.03
Guatemala	94.7%	3,507,977	10,570	139,430	1.86
Guinea	44%	2,009,276	1,983	73,921	0.99
Equatorial Guinea	67%		1,321	1,927	0.03
Guinea-Bissau	28,.7%		39	56	0.00
Guyana	91.8%	19,629	851	1,935	0.03
Haiti	45.3%	2,735,164	359	97,211	1.30
Honduras	91.9%	2,082,686	6,696	83,393	1.11
Hong Kong	100%	2,646,107	44,730	158,809	2.12
Hungary	100%	3,753,000	41,621	193,401	2.58
Marshall Islands	96.4%		562	820	0.01
Solomon Islands	66.7%		98	143	0.00
India	100%	299,727,860	1,547,000	12,852,746	171.37
Indonesia	98.5%	69,855,344	263,139	2,853,356	38.04
Iraq	99.9%	5,212,262	43,971	248,415	3.31
Iran	100%	24,056,109	254,724	1,222,074	16.29

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
Ireland	100%	1,799,221	27,203	103,296	1.38
Iceland	100%		18,679	27,256	0.36
Israel	100%	2,953,648	56,391	186,696	2.49
Italy	100%	25,020,120	297,150	1,318,059	17.57
Jamaica	98.9%	893,225	3,025	35,989	0.48
Japan	100%	55,704,949	902,842	3,286,587	43.82
Jordan	99.9%	2,291,955	17,384	106,387	1.42
Kazakhstan	100%	5,381,052	91,668	323,981	4.32
Kenya	75%	13,071,338	8,722	474,798	6.33
Kiribati	100%		27	39	0.00
Kosovo	100%		5,715	8,339	0.11
Kuwait	100%		59,278	86,497	1.15
Kyrgyzstan	100%	1,565,200	11,740	72,460	0.97
Laos	97.9%	1,254,263	4,059	50,261	0.67
Lesotho	47%	600,072	902	22,528	0.30
Latvia	100%	73,637	6,877	12,637	0.17
Lebanon	100%		17,708	25,839	0.34
Liberia	25.9%	923,685	348	33,160	0.44
Libya			25,693	37,490	0.50
Liechtenstein	100%	167	394	580	0.01
Lithuania	100%	1 204,383	11,306	59,072	0.79
Luxembourg	100%	259,519	5,817	17,662	0.24
Macau	100%	227,031	5,378	15,873	0.21
Northern Macedonia	100%		7,024	10,249	0.14

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
Madagascar	25.9%	5,304,084	2,117	190,588	2.54
Malawi	18%	4,091,853	1,515	146,857	1.96
Malaysia	100%	7,176,812	147,209	468,506	6.25
Maldives	100%	70,952	565	3,332	0.04
Mali	50.9%	3,484,826	3,040	127,624	1.70
Malta	100%	180,375	2,456	9,960	0.13
Morocco	100%	6,890,065	29,678	286,869	3.82
Mauritius	97.5%	364,285	2,800	16,963	0.23
Mauritania	44.5%		882	1,287	0.02
Mexico	100%	34,167,462	267,910	1,598,751	21.32
Federated States of Micronesia	82.1%		125	182	0.00
Moldova	100%	914,026	5,957	41,003	0.55
Mongolia	98.1%	774,771	6,933	37,504	0.50
Montenegro	100%	193,488	2,998	11,214	0.15
Mozambique	31.1%	6,885,971	13,390	262,957	3.51
Myanmar (Burma)	66.3%	12,978,359	18,024	485,085	6.47
Namibia	53.9%	590,931	4,184	26,994	0.36
Nepal	93.9%	7,075,702	6,562	259,701	3.46
Nicaragua	88.1%	1,326,800	3,738	52,356	0.70
Niger	17.6%	3,920,330	1,586	140,897	1.88
Nigeria	56.5%	42,057,041	29,011	1,529,048	20.39
Norway	100%	2,426,071	124,127	266,886	3.56

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
New Caledonia	100%		2,741	3,999	0.05
New Zealand	100%	1,906,474	41,165	127,461	1.70
Oman	100%	55,443	31,766	48,312	0.64
Uganda	42.6%	9,170,821	3,534	329,345	4.39
Uzbekistan	100%	6,586,983	49,204	304,647	4.06
Pakistan	100%	32,462,785	90,000	1,278,886	17.05
Panama	100%	1,165,778	9,258	54,719	0.73
Papua New Guinea	59%	1,645,457	3,777	63,678	0.85
Paraguay	100%	1,565,626	13,097	74,455	0.99
Netherlands	100%	7,874,258	110,682	439,861	5.86
Peru	95.2%	8,695,193	47,409	376,553	5.02
Philippines	94.9%	25,893,157	93,354	1,051,544	14.02
Poland	100%	13,666,831	152,573	705,755	9.41
French Polynesia	100%		544	793	0.01
Portugal	100%	3,876,822	48,035	207,137	2.76
Puerto Rico	100%	1,195,915	15,466	64,843	0.86
Qatar	100%		43,375	63,292	0.84
Central African Republic	32.4%	1,148,086	140	40,789	0.54
Democratic Republic of the Congo	19%	19,225,670	8,594	692,167	9.23
Dominican Republic	100%	3,004,226	16,067	129,644	1.73

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
Republic of the Congo	68.5%	1 ,281,072	2,018	48,230	0.64
Czech Republic	100%	4,465,680	63,920	251,133	3.35
Romania	100%	6,709,224	55,008	317,438	4.23
United Kingdom	100%	29,486,179	300,520	1,480,852	19.74
Russia	100%	56,771,478	965,156	3,415,217	45.54
Rwanda	34.7%	2,973,056	764	106,212	1.42
Samoa	100%	29,995	124	1,241	0.02
Sao Tome and Principe	71%		80	116	0.00
Senegal	75%	1,928,689	3,842	73,785	0.98
Serbia	100%	2,405,804	30,292	129,246	1.72
Seychelles	100%		403	588	0.01
Sierra Leone	26.1%	1,373,151	242	48,894	0.65
Singapore	100%	1,727,455	47,583	130,498	1.74
Slovakia	100%	1,948,989	26,237	107,181	1.43
Slovenia	100%	851,149	14,023	50,550	0.67
Somalia	35.3%		323	471	0.01
Sudan	59.8%	7,691,174	11,463	288,609	3.85
Sri Lanka	99.6%		13,438	19,608	0.26
South Sudan	28.2%	2,227,637	529	79,518	1.06
Sweden	100%	4,776,239	131,798	361,158	4.82
Switzerland	100%	3,901,112	56,353	220,134	2.94
Suriname	97.4%	149,741	1,663	7,719	0.10
Eswatini (formerly Swaziland)		23,986	1,682	3,302	0.04

Country	Access to electricity (2018) (%)	Households	GWh supplied	No. of km of lines	No. of poles (millions)
Syria	86%		14,263	20,812	0.28
Tajikistan	99.3%	1,485,317	16,085	75,977	1.01
Tanzania	35.6%	11,880,255	5,813	428,449	5.71
Chad	11.8%	2,811,841	213	99,709	1.33
Thailand	100%	18,042,640	185,852	909,000	12.12
East Timor	85.6%		100	145	0.00
Togo	51.9%	1,693,139	1,251	61,677	0.82
Tonga	98.9%		51	74	0.00
Trinidad and Tobago	100%	415,308	8,246	26,713	0.36
Tunisia	99.8%		15,838	23,110	0.31
Turkmenistan	100%		15,090	22,019	0.29
Turkey	100%	20,424,610	251,376	1,088,815	14.52
Ukraine	100%	16,972,715	128,806	787,937	10.51
Uruguay	100%	1,269,537	11,812	62,114	0.83
Vanuatu	61.9%		65	94	0.00
Venezuela	100%	6,565,128	64,660	326,428	4.35
Vietnam	100%	25,503,951	216,994	1,218,200	16.24
Yemen	62%	4,469,863	2,653	161,880	2.16
Zambia	39.8%	3,485,901	13,097	142,337	1.90
Zimbabwe	41%	3,795,226	7,401	144,960	1.93

List of abbreviations

°C	Degree Celsius
ADEME	French Environment and Energy Management Agency
AFD	Agence française de développement
APAC	Asia-Pacific zone
CAS	Chemical Abstracts Service (U.S.) (see glossary)
CCA	Copper, chromium, arsenic (mixture of these three elements)
CIRED	International Center for Research on Environment and Development
CLP	Classification, Labelling, and Packaging of chemicals and mixtures (EU regulation)
CO_2	Carbon dioxide
ECHA	European Chemicals Agency
EFTA	European Free Trade Association
EIB	European Investment Bank
EPA	Environmental Protection Agency (U.S.) (see glossary)
EU	European Union
EUR	Euro
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act (federal law, U.S.) (see glossary)
GWh	Gigawatt-hour (1 GWh = 1 million kWh)
IARC	International Agency for Research on Cancer (WHO) (see glossary)
IED	Industrial Emissions Directive (European directive)
ISO	International Organization for Standardization
k	Kilogram (or thousand)
KfW	Kreditanstalt für Wiederaufbau (German development bank)
km	Kilometer
kt	Kiloton (equivalent to one thousand tons)
kWh	Kilowatt-hour

LCA	Life Cycle Assessment (see glossary)
m	Meter
M	Million
NEB	National Electricity Board (Morocco)
ORNL	Oak Ridge National Laboratory (U.S.)
PAHs	Polycyclic aromatic hydrocarbons (see glossary)
PBT	Persistent, bioaccumulative, and toxic (see glossary)
POP	Persistent organic pollutants
RAC	Risk Assessment Committee (ECHA) (see glossary)
REACH	Registration, Evaluation, Authorization and restriction of Chemicals (EU regulation)
RED	Reregistration Eligibility Decision (EPA)
SEAC	Socio-Economic Analysis Committee (ECHA) (see glossary)
TCO	Total Cost of Ownership
TWC	Treated Wood Council (U.S.)
TWh	Terawatt-hour (1 TWh = 1 billion kWh)
USD	United States Dollar
WHO	World Health Organization (United Nations)
WWF	World Wildlife Fund

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