Value chain analysis of biobased components for paints and adhesives

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Summary

The paint and adhesive industry is facing a possible shift regarding the origin of the raw material used, i.e. a transition from today's fossil-based raw materials to biobased. The conversion will require research and development of techno-economically efficient processes to produce these raw materials from various alternative biomasses without competing with e.g. food production or other values that are considered essential for the environment and the climate. A change must be perceived as valuable for all players in the value chain, where the value can be economic, environmental, market shares, branding, etc.

The project "Value chain analysis bio-components for Paint and Adhesives" was conducted during 2020 with parties representing different parts in value chains for paint and adhesives, respectively, with the aim of studying how the cost of an expensive raw material propagates through the value chain. For typical value chains, it turns out that the cost is diluted through the chain and theoretically the price of the product increased by 1-4% for paint.

Bio-based adhesives with a renewable content of 30–50% are available on the Nordic market in plywood boards. The cost increase for such an adhesive is stated to be below 10%, which affects the cost by a maximum of 1% increase.

Other possible factors that may affect a change are increased regulatory requirements linked to sustainability such as certification of buildings, CO_2 calculations of raw materials, an increased public debate demanding more sustainable and climate-smart products. The price pressure that prevails in both industries and that crude oil is currently cheap is an obstacle. In addition, it seems difficult to get a dialogue between decision-makers and producers, which means that knowledge of new alternatives is not transmitted.

The study was initiated and funded by Climate-Leading Value Chains within the program for Climate-Leading Process Industry. The program is generally funded by the Vinnova and Västra Götaland regions and is coordinated by Johanneberg Science Park and RISE through the West Swedish Chemistry and Materials Cluster. The project has been run by Chalmers Industriteknik and RISE Processum with participants from Södra, Vattenfall, Stora Enso, Moelven, Isotimber, DAW, Beckers, Akzo Nobel, Allerby Måleri and Riksbyggen.

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1. Background

Raw materials for paints and adhesives are in many cases fossil-based bulk products on price-squeezed "commodity" markets. Despite the fact that there is a demand for renewable construction and interior design products driven by both the public and private companies with an environmental profile, renewable alternatives may have difficulties establishing themselves as they have a raw material cost than conventional alternatives.

The paint and adhesive industry have for a long time strived to reduce the content of fossil components in the products. The focus for this work has been to improve the work environment or connected to regulatory perspectives and permits. Despite this, the building blocks of the binders in paints, varnishes and adhesives are generally still monomers of fossil origin. The possibility of converting these fossil monomers to bio-based monomers thus constitutes an interesting potential of a reduction of the fossil content of today's paint and adhesive products.

The raw materials of most importance for the preparation of these monomers are classical basic chemistry raw materials such as ethylene, propylene, methanol, ethanol, butane, benzene, toluene, and xylene. These molecules also constitute important basic raw materials for the chemical industry in general, such as Stenungsundsklustret. Starting from biobased raw materials rather than fossil based, in the production of these monomers, will imply a significant price increases for the monomers and thus a significant cost increase for the first links in the respective value chain. The question is how the magnitude of the cost is propagated through the value chain and how it can be absorbed by the various links so that the final price to the end user is on an acceptable level.

Previous focus for the paint industry has been to reduce the content of the organic solvents, film formers and preservatives to develop water-based systems. In both professional and consumer paint, the industry has in principle substituted all organic solvents with water today. On the other hand, in industrial paints, organic solvents are still used, although here the trend is decreasing both through new technologies such as e.g. UV cured systems, high-solid systems and the use of bio-based solvents.

Over the last 20 years, the interest for developing biobased adhesives has increased. The aim has been to phase out ingredients of fossil origin and toxic substances contained in for example wood adhesives, and then in particular formaldehyde and phenols, found in chipboard, fibreboard, other building boards (such as plywood and oriented strand board, OSB) and load bearing adhered wooden structures (glulam and cross-glued wood) have been in focus. The functional requirements that biobased adhesives must meet, in order to replace commercial synthetic adhesives, are above all: comparable price, similar properties in the manufacturing process of wood products and the same water and heat resistance.

One track in the development of bio-based chemicals is to produce chemicals identical with the current components but derived from biomass instead of fossil oil. The source of these components can be either ethanol or methanol based on biomass from forests, agriculture or household waste, biogas or gas from landfills or recycled carbon dioxide can also be a source. There are also development tracks where new adhesives based on natural biopolymers replace the current fossil adhesives. These biopolymers can be prepared from lignin, cellulose, hemicellulose, tannins or proteins.

The project, Value chain analysis of bio-based components for Paint and Adhesives, has been initiated and financed by Climate-leading Value Chains within the program for Climate-leading Process Industry. The program is funded by Vinnova and Västra Götaland region and is coordinated by Johanneberg Science Park and RISE through the West Swedish Chemistry and Materials Cluster. The project also has a strong connection to another project in the Climate-Leading Process Industry, Bioolefins (4.2.2 Bioeten).

2. Purpose and Goal

The purpose of the project is to map various value chains and investigate how the cost increase propagates through the value chain when biobased raw materials are being used instead of fossil based. In addition to this, the project will deliver suggestions for continued work to develop biobased paints and adhesives for healthy and climate smart buildings.

The project goal is to:

- Increase the understanding of cost development in the various steps of the value chain and thus the cost effect for the end user to choose a more climate-smart alternative
- Basis for continued work to develop biobased paints and adhesive products
- Identify the most important “drivers and barriers” for the players in the value chain. This can for example be pricing, policy issues, laws, regulations, mass balance, procurement requirements, etc.
- Deeper understanding of the market
- Depending on time and budget, perform a mapping of the methanol market

3. Implementation

The work has included various tasks to try and get as comprehensive a picture as possible based on information from literature and patents but also on the parties' perception and knowledge of market conditions and driving forces.

3.1 Participants

The following participant have, besides Chalmers Industriteknik and RISE Processum, contributed to the outcome of the project with their knowledge and experience:

Vattenfall, Södra, Moelven Isotimber, Stora Enso, Akzo Nobel, Beckers, DAW, Allerby Måleri samt Riksbyggen

3.2 Literature and patents

Information has been obtained from previous reports on biobased components in paint and adhesives, as well as from the trade press regarding trends and news. A patent search has been performed, both on a product level but also on relevant constituents.

The Orbit Intelligence patent database has been used to search for patents in the field of paints. The search has mainly been based on IPC classes and keywords.

For biobased adhesives, the patent database Espacenet has been used instead to investigate which companies that are most active.

3.3 In-put from the market

3.3.1 Interviews

The parties for each of the value chains, i.e the project participants, have been interviewed in order to develop an understanding of how the market works, trends, developments, obstacles and opportunities.

3.3.2 Strategic Tool for Circular Conversion ” Verktyg för Cirkulär Omställning – SVCO”

The Circular Economy group at Chalmers Industriteknik, facilitated two workshops, based on the SVCO-tool that they have developed previously. The Strategic Tool for Circular Conversion, SVCO, is intended to be used to allow the parties in a value chain to illustrate in a simple way how one is affected by or affects the three factors Environmental, Economic and Social, of the proposed change. Thereafter possible solutions how to overcome the obstacles brought up by the parties are discussed and voted upon.

The different sub-factors are:

Environment	Emission to air	Emission to land and wate	Use of resources	Greenhouse gases
Economy	Revenue	Cost	Investment	Capital
Social	Working conditions	Employment	Health and security	Equality and Human rights

In this project, two workshops were conducted, one for paints and one for adhesives. In both the workshops participants representing the various links in the value chain participated. The challenging goal set was:

”100% biobased consitutents in paints / adhesives by 2030”

3.4 Paints

Paint is an extensive area that can be divided into two major groups:

- Professional and consumer
- Industrial

In this limited project a segment within each of the major groups have been selected. Within professional and consumer, it is decorative paint and for industrial it is coil coating.

Paint is frequently used both in industry and by consumers. There are biobased paints on the market today for decorative painting indoors, i.e. wall and ceiling, but the market and demand is still small. The major challenge for a transition to completely biobased paints lies in replacing the fossil-based solvents that are still used, mainly in the industrial paints, but also to some extent in consumer paints. Some of the organic monomers used in the production of binders have a complex structure, aromatic, and are therefore considered difficult to produce from renewable raw materials today.

The paint industry is considered a “commodity” industry that is very price sensitive, and with today's low crude oil prices it becomes really difficult to compete with the traditional fossil-based paints. Irrespective of this a product which is biobased generally means an advantage in market communication.

Total paint production is expected to continue to increase with a Compound Annual Growth Rate, CAGR, of 5.4% according to Coatings World[1]. According to the same market report, “eco-friendly” is expected to continue to gain market share, which in many cases refers to a transition to water-based systems in many markets where solvent-based dominates today. The consumer market today accounts for about 28% of the total, based on revenue for the companies

3.5 Adhesives

Adhesives tend to be found in the most diverse areas. During the last 10 years, the trend has been that the number of bio-based adhesives has increased. The primary purpose has been to eliminate the fossil dependencies and the toxic substances found in the adhesives. For example, the adhesives used in the wood industry for chipboard, fibreboard or plywood, contain the toxic chemicals formaldehyde and phenol.

Bio-based can mean a positive attitude for a brand, but also that strict requirements are added to them. In addition to being environmentally friendly and sustainable, they must also compete with low prices, adaptation to existing production systems and have the same water and heat resistance to replace commercial synthetic adhesives.

Of the world's total consumption of adhesives, the wood industry consumes about 70% with its wide range of products from building elements to furniture. There are also several different types of adhesives depending on what is to be adhered and what functionality is required. It has therefore been necessary to set up boundaries in the project. The value chain reported here is mainly adhesives for chipboard, fibreboard, and plywood. There are several reasons for this prioritization:

- they are common wood products
- the proportion of adhesives in these products are relatively large

[1] https://www.coatingsworld.com/contents/view_market-research/2020-10-12/coherent-market-insights-paint-and-coatings-market-to-surpass-220-billion-by-2027/70769

- important to phase out toxic chemicals in the adhesives
- the proportion of bio-based in the adhesive is gradually increasing

On the other hand, no delimitation is made in the Market Study for the adhesives. This describes the global adhesive market, who are the major adhesive manufacturers, who have bio-based adhesives on the market and what is happening on the research front.

4. Results

4.1 Paint

4.1.1 Value chain Paint

Each application for paints can be assumed to have a value chain of its own. This project has chosen to base the further work on a value chain descriptive of a consumer and professional paint, see Figure 1. The reasoning behind this is that the representation of project participants is best represented by this value chain. Regrettably, no manufacturer of binders has actively participated in the project, but information regarding the composition for cost analysis has still been obtained.

Figure 4. Value chain for consumer and professional paints

The project has taken both consumer and professional paint into account, i.e., water-based latex paint for indoor applications, and industrial paint for coil coating of sheet metal that are solvent-based. Outdoor paint, i.e., facade paint for wood and mineral substrates, has not been covered by this project.

4.1.2 Composition of paints

Consumer paints for painting indoor walls and ceilings are today generally water-based in the Nordic countries. In some other countries in southern Europe and to some extent globally, solvent-based paints are still used for indoor applications.

The composition of a water-based paints for indoor use depends on the gloss of the paint, the lower the gloss the less binder it contains. The gloss of paints and varnishes is determined according to ISO 2813: 2014[2]. In general, gloss is translated as, full matt (0–5), matt (6–10), semi-matt (11–29), semi-gloss (30–59), glossy (60–89) and high-gloss (90–100). A typical composition for an indoor paint is found in Table 1. Paint used for floor molding and corniche often still contains some solvents such as propylene glycol, see Table 2.

[2] ISO 2813:2014 Paints and varnishes – Determination of gloss value at 20°, 60° and 85°

Table 1. Composition of water-based paint – indoor application

Component	Type	%
Organic binder	Acrylate	5-25
Inorganic (pigment paste)	Titaniumdioxide-TiO_2, Calciumcarbonate-$CaCO_3$ and Clay-$Al_2Si_2O_4$	25-50
Emulsifier	Hydroxyethylcellulose	1-2
Water		40-55

Table 2. Composition paint for floor molding, corniche – indoor application

Component	Type	%
Organic binder	Acrylate	ca 30
Inorganic (pigment paste)	Titaniumdioxide-TiO_2	ca 20
Water		ca 40
Solvent	Propylene glycol	ca 10

Industrial paint, which in this project has consisted of coil coating for industrial painting of sheet metal, generally contains solvents. Production of coil coated sheet metal is a precision manufacturing, with high demands on the strength of the finished colour film as well as fast drying, high flexibility, and high uniformity, at very high production speeds. To achieve properties of the paint that enables this, solvents are still being used, preferably aromatic with high boiling point, see Table 3. However, the solvents are being used as an energy source in the production for heating furnaces for drying / curing the paint.

The pre-painted sheet is then used to manufacture roofs, chimneys, downpipes, gutters, facade elements, etc., but also for consumer products such as appliances.

Table 3. Composition of coil coating

Component	Type	%
Organic binder	Polyester	ca 40
Inorganic (pigment paste)	Titaniumdioxide-TiO_2, Silica-SiO_2	ca 30
Solvent (aromatic)	C9-C16	ca 30

SSAB has developed a technology where RME, Rapeseed methyl ester, is part of the solvent in the paint. The bio-based RME acts as a reactive diluent, ie it replaces a proportion of the fossil solvent and contributes to a lower viscosity so that the paint has the desired application properties and reacts with the binder during the drying process.

4.1.3 Patent

Patent search for paints has been based on IPC classes and keywords. The restriction has been that reported patent families must have at least one member that is published in Europe and when searching for active players, the search has been limited to the last 10 years. The focus has been on trends and statistics on specifically biobased components and no analysis of the patents or their content has been made.

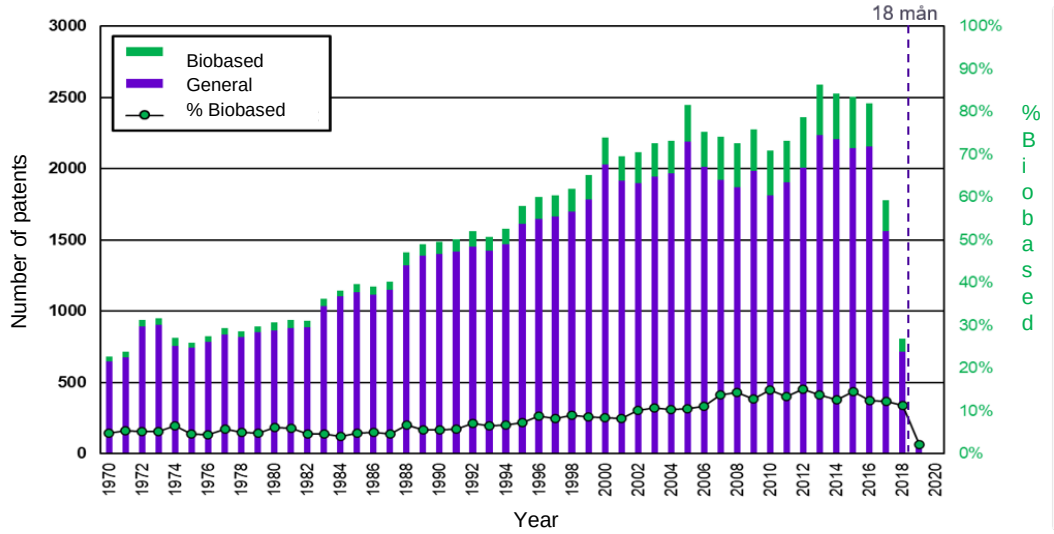
Used search term that scans the entire document:

Bio?based OR (bio 2W based) OR (renew+2W (sourc+ OR resource+ OR(raw?material OR (raw 2W material)))) OR biomass OR non?fossil OR vegetab+

Patent class

Search in IPC C09D, representing paint, yields 92,718 patent families. If biobased is added as a search term, the number is reduced to 8,197. Applicants or owners of the patents are mainly the major global chemical companies.

Most patent families are owned by DOW Global Technologies closely followed by BASF and 3M. BASF Coatings is also represented among the Top-10 together with Rohm Haas, Xerox etc. With the addition of the biobased restriction, it is still the same actors even if the mutual order is somewhat changed.



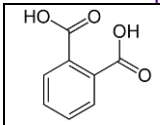
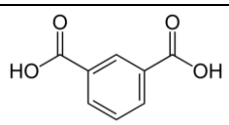
Figur 2. IPC C09D, Year of priority

Figure 2 above shows a reduction in the number of patents from 2017 onwards. The process of obtaining a patent approval is 18 months, which may partly explain the low number of patents for the years 2018–2019, as the search was made during June-July 2020. However, it does not explain the decline in numbers in 2017. The level regarding the number of patents with " bio-based" is unchanged, around 10–15%, of the total, regardless of the number of patents from around 2007 onwards.

Components for binder

In order to get a clear picture of biobased components, a similar search was made for some of the more interesting monomers used in the manufacturing of paints. The monomers selected were phthalic acid, isophthalic acid, phthalic anhydride, adipic acid, neopentyl glycol, trimethylolpropane, acrylate and acrylic acid. For a compilation of used search terms and number of hits, see Table 4.

Table 4. Components for binder, search term and No: of hits

 Phtalic acid		 Isophtalic acid	
+pht?al+ 2W acid,	46 355	isopht?al+2W acid	9 736

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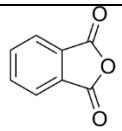
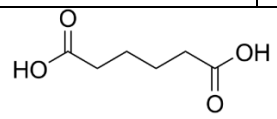
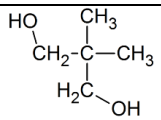
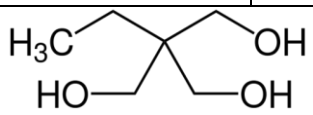
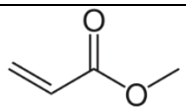
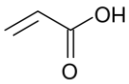
+ ”bio”	6 790	+ ”bio”	1 157
 Phtalic anhydride		 Adipic acid	
phtal+2W anhydride+	8 565	adipic 2W acid or hexanedioic acid 2W acid	16 641
+ ”bio”	803	+ ”bio”	3 164
 Neopentyl glycol		 Trimethylol propane	
Neopentyl 2W glycol	6 259	Trimethylolpropane or trimethylol 2W propane	5 672
+ “bio”	1 128	+ “bio”	947
 Acrylate		 Acrylic acid	
+acrylate+ or propenoat+	169 234	+acryl+ 2W acid or propenoic 2W acid	90 036
+ “bio”	21 373	+ “bio”	13 776

Again, it is the large chemical companies that are represented, but in addition there are a number of applications from the cosmetics and hygiene industry, which is interpreted as these monomers are also used to manufacture for example preservatives for cosmetic products.

Conclusively, it can be said that for all “building blocks”, the proportion of patent families that contain words related to biobased has increased since the 1990s, but the activity level has decreased over the last years, see Table 5. The column "When?" in the table refers to which year there were most patent actives per substance.

If you look at which companies that are the owners of most patent families, it is more or less the same company that owns the most patents in general and also contains words that relate to biobased, ie. BASF, DOW, 3M etc. The companies with the widest portfolio, ie. have been most active in applying for patents for most variants of the bio-based building blocks, are BASF, L’Oreal and Arkema.

Table 5. Percentage of patents per biobased monomer and 10-year period.

Percentage Biobased							
	Year					Highest %	In Year
	1970-1979	1980-1989	1990-1999	2000-2009	2010-2018		
Phtalic acid	7	8	12	24	28	32	2011
Isophtalic acid	4	4	8	19	26	33	2008
Phtalic anhydride	6	6	8	16	20	21	2013
Adipic acid	7	10	17	29	38	43	2015
Neopentyl glycol	4	7	14	24	35	37	2017
Trimethylol propane	5	7	12	20	23	29	2010, 2014
Acrylate	5	5	9	17	20	22	2009
Acrylic acid	5	7	12	21	24	26	2005

The patent search shows that there is or has been an interest in manufacturing these building blocks from raw materials other than oil. However, it is not clear whether these patents have led to any industrial activities.

Perstorp[3] has two products in their portfolio with the above monomers. Neopentyl glycol, trade name Neeture, with 20 or 40% biobased and trimethylolpropane, trade name Evyron, with 20 or 50% biobased. They are both mass balanced[4], i.e.. in the production both biobased and fossil-based raw materials is used. Both neopentyl glycol and trimethylolpropane can have methanol as one of the building blocks in manufacturing, either 2 or 3 methanol molecules per monomer, respectively. Perstorp also has pentaerythritol which is used in alkyds in 40 and 100% bio-based versions which is marketed under the brand name Voxtar.

Adipic acid, which is an important component mainly for the production of Nylon 6.6, is also available as bio-based produced by Genomatica[5]. The production seems to be used to 100% by the company themselves for the production of their Nylon 6.6.

Roquette[6] has taken over the production of bio-based succinic acid, which was described in the previous UDI project as a possible component for alkyd paints.

As mentioned earlier, solvent-based paints are still used in industrial painting processes, but it is also common in some European countries for consumer paints. The EcoBioFor[7] project, 2014–2016, had solvents as the focus of its work towards more bio-based paints.

Paints available on the consumer market with partly biobased content are for example DSM with Decovery, Alcros A1 and DAW with IndecoGeo.

[3] https://www.perstorp.com/
[4] https://www.biobasedeconomy.eu/centc-411-bio-based-products/
[5] https://www.genomatica.com/
[6] https://www.roquette.com/
[7] https://cordis.europa.eu/project/id/605215/reporting

4.1.4 Input from the market

Interviews

Participating parties were initially interviewed in the project to get an idea on how they saw the interest in biobased paints from the market, what obstacles they experienced and how they saw upon the future.

Most of the interviewees consider the paint industry to be a conservative and price sensitive trade with a few, dominant players. The price sensitivity is considered to be a major obstacle for the conversion to biobased paints. Everyone interviewed agreed that using more biobased will imply cost increase. This is an effect of the limited production of biobased raw materials and hence that there is little or no scale effect. According to one of the interviewees, some customers also expects improved performance based on the higher price, which is difficult to deliver. In addition, crude oil prices are currently very low, which further speaks for the fossil-based products.

Procurement is done mostly on price, but other properties such as opacity, application properties, splashing, odour and drying times is also assessed. In addition, there has been some focus on working environmental hazards or toxic issues, these issues are often pursued by Sveriges Färg och Lim Företagare, SveFF, and often apply to various additives in the paint like preservatives that are considered allergenic and titanium dioxide that is believed to be carcinogenic.

Replacing a fossil-based component with its chemical equivalent based on renewable raw material, so-called drop-in, does not mean a change in the end product. The big challenge arises when it is not possible to produce drop-in variants of bio-based raw material, which means that you as a manufacturer of binders or paints must work on your recipes. Which in turn requires extensive testing of the product to ensure that properties and functionality are the same, this can be extra important in cases where the warranty periods are long.

Focus for consumer paints is to change the binder because the paints are already water-based, while for industrial paints it could also be interesting to find alternative solvents. The latter is a challenge as aromatic solvents are often used based on the process properties and where there is no direct substitute or drop-in solution.

Another obstacle experienced by a majority of those interviewed was the difficulty to reach the decision-makers at the builders, architectural firms or property owners, i.e. it was difficult to create knowledge about and thus an interest and a demand for bio-based paints. Corresponding comments also came from the other side, where it is not always known that there are alternatives to the traditional fossil-based paints. If you as an end customer want a bio-based paint, you must be careful to specify it as a requirement, otherwise there is a risk that it will disappear as there may be many different contractors involved.

The paint constitutes a very small part of the cost of a construction and yet it is a concern that the end user is not willing to pay. The opinion is that it should be possible to communicate biobased paint but that the arguments might not be the right ones. An

important factor that could make an impact is classification of buildings. Previously, there has been a focus on energy consumption in buildings, but the interest in sustainability based on the selection of materials is increasing. Several of the players believe that some form of a climate declaration of buildings will come and it is assumed it will contain some measure such as CO_2 footprint or similar. Today there are Sunda Hus, LEED, BREEAM m.m. According to one of the interviewees, the label Sunda hus may result in a certain amount of financial pay-back. All forms of requirements such as laws, policies, etc. helps accelerate the conversion. At the same time, there is a view that the Public Procurement Act can be a problem if you have a unique solution. Questions about the possibility of reusing building elements are increasing, but the fact that something is painted should not be an obstacle.

For those customers who still demand bio-based, it is important that the raw material does not compete with food production, and that it can not be linked to deforestation or palm oil.

SVCO-Workshop Paint

The participants in the workshop for Paint were Vattenfall, Södra, Akzo Nobel, Beckers, DAW, Allerby Måleri and Riksbyggen.

Before the workshop, the participants had worked through the tool and answered how they saw that they would be affected or affected by a change to "100% bio-based components in paint by 2030". During the workshop, the results obtained were presented and the parties were given an opportunity to develop their thoughts to increase the mutual understanding. Subsequently, various solutions were discussed, which the parties voted on afterwards. A summary can be found in Appendix 1.

The outcome shows that a transition to biobased components is considered to have a positive impact on the environment, the participants were either positive or neutral to the different factors in the tool. The solutions that most participants thought would endorse a change are systems/requirements requiring sustainability labels and resource efficient way-of-working, ie. recycle waste, green energy, right molecules, etc.

For the economy, one sees obstacles with increased costs and the impact on capital, while at the same time looking positively at income. Solutions that can lead to success are believed to be working with interested actors who are not so price sensitive, link to "eco-labelling" of buildings, ensure that the environment can be prioritized in "public procurement", more active collaboration through the value chain, etc.

Regarding the social impact, the results are either positive or neutral where it is believed that you get a positive impact on employment and on health and safety. Here, according to the solution proposals, it is important not to compete with food, but also to work with labelling and procurement processes.

4.1.5 Market study

Market description

"The total paint consumption in Sweden was 114 million litres during the years 2018-19. Outdoor paints for" on-site painting "are 88% waterborne", 2020 [8].

The market share for 100% bio-based paint globally is currently assumed to be about 5% with a value corresponding to about € 7 billion, while it is less than 3% of the volume, compared to the total value for paint of about € 141.4 billion years 2018[9]. If you look at the value of paints that have a partially biobased content, it is assumed to be about € 14 billion and represent about 10% of the volume of paint.

The market is expected to continue to grow, largely based on consumers' increased awareness and demand for bio-based but also due to various regulatory requirements or eco-labels[10]. Examples of Ecolabelling are for example Sunda Hus, Byggvarubedömning, BREEAM, BASTA etc.

Within the EU, a fact sheet on bio-based paint has been produced to support procurement, mainly with the argument of reducing greenhouse gas emissions[11].

Market forces

Possibilities/Driving forces

Increased demand for bio-based products together with an active legislation or other regulations will be the strongest driving forces for a transition of the paint industry to more biobased. At the same time, it will drive development so that the supply of raw materials will no longer be an obstacle, which is likely to have some economies of scale and hence, affect the price, so that the products will be more competitive in terms of price. At the same time, there is a risk of tougher competition for the raw material as different industries search for new raw materials from the same sources.

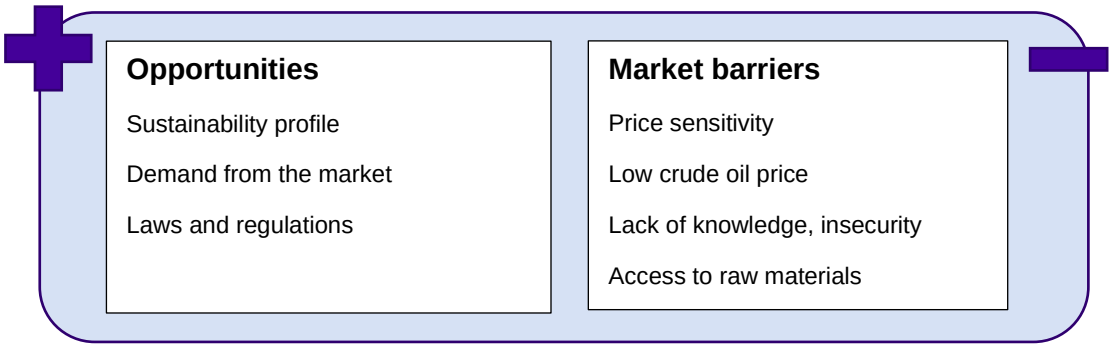


Figure 3. Opportunities and market barriers

[8] http://www.teknikhandboken.se/handboken/byggnadsmaterial-i-kretsloppet/farg-for-platsmalning-av-plat/tillverkning-av-farg/

[9] https://www.european-coatings.com/Raw-materials-technologies/Bio-based-coatings-Small-market-full-of-potential

[10] https://www.european-coatings.com/Markets-companies/Bio-based-coatings-Growth-worldwide

[11] https://biobasedprocurement.eu/wp-content/uploads/2016/02/Biobased-Coating.pdf

4.1.6 Cost estimate

Background

Professional paint and consumer paint need no further presentation, but it can be noted that today basically all these paints are water based and it is rare that fossil solvents are used. The binder used in these paints today is largely acrylates.

Coil coating means that metal strips are painted in an industrial process. The strips are pulled, after application of paint, through an oven and immediately rolled up on a roll. There are high demands on short drying time and flexibility on the paint layer. This is due to high line speed and the subsequent processing of the metal sheets turning them into various products. Examples of products made of strip lacquered sheet metal are roofing sheets, gutters, facade sheets, etc. These paints are still diluted with fossil solvent which is used in the drying process as fuel used for heating furnaces in which the paint is dried. The binders used in coil coating are polyesters that are crosslinked with melamine resins.

Paint roughly comprises four components binders, pigments, solvents, and additives. The largest fossil element of these four components is the binder, which in turn is made up of small building blocks, monomers. The binder manufacturer polymerizes the monomers into binders which are diluted with fossil solvent or water. The solvent is added to lower the viscosity so that the final paint has the desired rheological properties. In our calculations, we have therefore focused on the binder and the fossil solvent, respectively.

Calculations

In this project the value chain has been represented by players from monomer manufacturers to sheet metal processors and professional painter respectively. In the value chain before the monomer manufacturer, there are usually three players:

- Crude oil supplier or corresponding when biobased
- Refinery
- Chemical industry, for example aldehydes (SEKAB, Perstorp, etc.)

In Table 6 there is an explanation regarding assumptions and how calculations have been made.

Table 6: Calculations of cost development through the value chain

Monomer producer	Producer of binder	Paint manufacturer	Professional painter/Coil coating	Sheet metal worker/Contractor
Hypothesis: price of monomers / solvents increases 100%	1. Percentage of monomer / solvent has been obtained from data sheets and literature for the binders. 2. The raw materials proportion of the price was obtained through interviews	1. Percentage of monomer / solvent has been obtained from data sheets and literature for the binders. 2. The raw materials proportion of the price was obtained through interviews	Proportion of the price to customer that is the cost for the paint obtained from interviews	Price increase after contractor and sheet metal worker has not been analysed.

The starting point has been the monomer manufacturer due to the representation in the project. The cost, of the monomers used, has assumed to increase by 100%. The cost effect for subsequent steps has then been calculated based on literature, data sheets, paint recipes and interviews with parties or other actors, see Table 6. This is to analyse how much a doubling of the initial raw material price means in material cost increases for contractors and sheet metal workers at the end of the value chain. No account has been taken to factors other than the increase in raw material costs in the calculations, i.e., absolute margin has remained at the same level despite increased sales caused by higher raw material prices, increased cost of disposal due to higher raw material prices has not been considered, etc. Input data for the calculations have been obtained by studying literature, data sheets, paint recipes and interviews with project partners and others representing links in the value chain.

The estimated change in cost through the value chain applies to cases where all necessary information has been obtained. The calculations are closely linked to the composition of the paint, which in turn is controlled by the application area. Calculations made can therefore not be generalized to apply to all other paint types and applications.

The result of the calculations with the hypothesis that the biobased monomer price is doubled compared to the fossil-based alternative. For consumer and professional paint, the cost increase is less than 1%, Table 7.

Tabell 7. Cost development professional and consumer paint

	Consumer and Professional Paint								
	Monomer producer		Producer of Monomers		Paint manufacturer		Painter		Contractor /end-user
	Raw material	Price increase transferred	Material cost	Price increase transferred	Material cost	Price increase transferred	Cost increase paint	Price increase to customer	Cost increase
Gloss 2	100%	55%	55%	41%	41%	2%	2%	0,2%	0,2%
Gloss 7	100%	55%	55%	41%	41%	5%	5%	0,5%	0,5%
Gloss 20	100%	55%	55%	41%	41%	6%	6%	0,6%	0,6%
Cornice	100%	46%	46%	35%	35%	6%	6%	0,6%	0,6%

For coil coating similar calculation gives approx. 1% cost increase when excluding the solvent and 4% cost increase when the fossil-based solvent has been hypothetically replaced by bio-based solvent, see Table 8.

Table 8. Cost development, Coil coating

	Coil coating								
	Monomer/ Solvent		Producer of binder		Manufacturer of paint		Coil Coating production		Sheet metal
	Raw material	Price increase transferred	Material price	Price increase transferred	Material price	Price increase transferred	Material price	Price increase transferred	Price increase
Excl. Solvent	100%	60%	60%	42%	42%	9%	9%	1%	1%
Incl. Solvent	100%	100%	100%	89%	89%	39%	39%	4%	4%

The cost increase for the end user will thus be relatively marginal, about 1-4%, according to these theoretical calculations. The consequence for the players that are early in the chain, here monomer manufacturers, binder manufacturers and paint manufacturers, on the other hand, will be extensive and theoretically this means a cost increase of 40–100%. This increase means a costly reduction in the margin for these players in percentage terms.

To overcome this obstacle, a dialogue between the various actors with the aim of spreading the financial risks throughout the chain, could be an opportunity. Other possibilities are that the driving forces mentioned earlier, such as demand, laws or

other political control, will drive a change without taking into account the financial conditions of the companies. Another possibility would possibly be to calculate the margin in another way or to include sustainability values in the assessment of a company's accounts proposed during the interviews

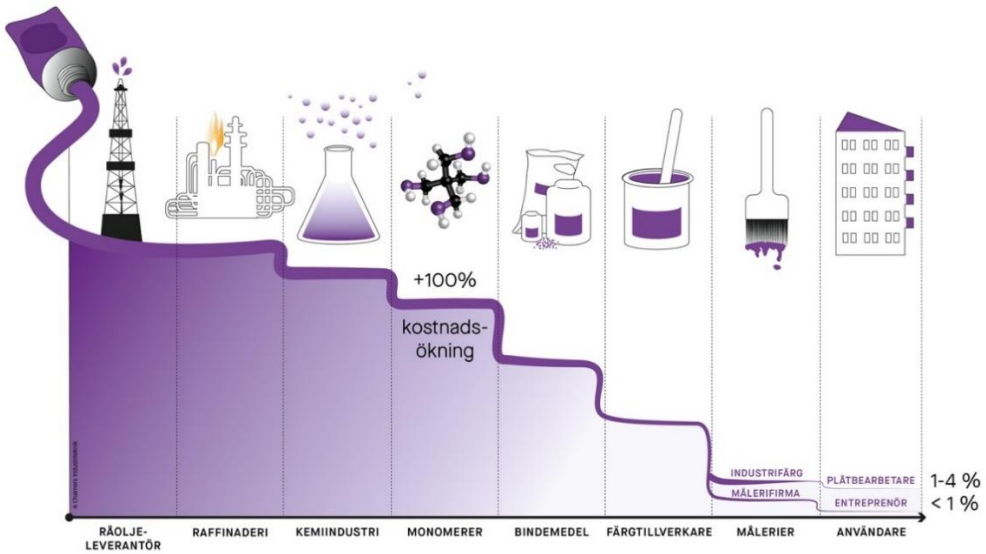


Figure 4. Cost development throughout the value chain, CIT

Figure 4 is a more illustrative picture of the development of art through the value chain.

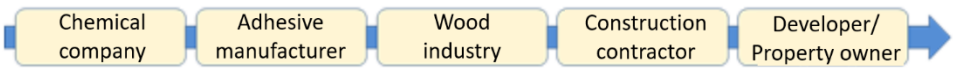
4.2 Adhesives

4.2.1 Value chain Adhesives

The value chain for adhesives differs in the first link depending on the type of industry that manufactures the binder; a chemical company or a forest industry company.

Parties from the entire value chain have participated in the project. It is not uncommon for the same company to represent several links in the value chain.

Value chain for conventional (fossil) adhesives



Value chain for lignin-based adhesives

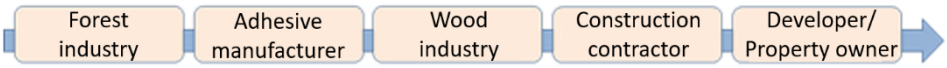


Figure 5. Value chain for adhesives

Since bio-based adhesives also consist of fossil chemicals (e.g., phenol), this means that the adhesive manufacturer buys the raw material from both the forest industry and the chemical industry.

4.2.2 Composition of adhesives

Fossil-based adhesives

Adhesives have different composition depending on what is to be adhered and what functionality is required. Below is a summary of the most common types of adhesives for the wood industry, which are predominantly made from fossil raw materials. Bio-based adhesives are treated in a special paragraph.

Phenol / formaldehyde (PF)

PF polymers are the oldest class of synthetic adhesives developed at the beginning of the 20th century. Phenol / formaldehyde adhesive consists of phenol which is reacted with formaldehyde in water (PF). The reaction is not reversible, which is why PF-adhered boards emit only negligible amounts of formaldehyde, compared to UF-adhered boards. PF is the most commonly used adhesive for plywood and OSB (Oriented Stranded Board). It provides a strong adhesive joint, is resistant to both moisture and heat, and is used for wooden boards to be used in outdoor environments. In many cases, if moisture resistance is not needed, a UF adhesive can be used at a lower cost. Formaldehyde can be included in the adhesive used when making the chipboard, but the substance can cause allergies and there are rules for how much may leak from goods is allowed.

Urea-formaldehyde (UF)

Urea / formaldehyde adhesives is used indoors and is the dominant binder for plywood, chipboard and MDF. It provides a strong adhesive joint, cures quickly, is non-flammable and is relatively inexpensive. A major disadvantage of UF adhesives is their poor water resistance. UF adhesives are believed to depolymerize, resulting in a continues release of formaldehyde.

Melamine / urea / formaldehyde (MUF)

Melamine / urea / formaldehyde adhesives are used to improve, among other things, the moisture resistance of wooden boards. Like formaldehyde adhesives, MUF adhesives have a high moisture resistance, but are most often used for finger joints, paper treatment and paper coating as well as plywood. What limits the MUF adhesives are the high cost associated with the high cost of melamine.

Methylene diphenyl diisocyanate (MDI)

MDI adhesives are used as an alternative to PF adhesives, mainly in composite products, with a slower hardening PF adhesive at the surface layers. The higher cost of the adhesive is balanced by the rapid reaction rate, its efficiency and its ability to adhere to surfaces that are difficult to adhere to. The use of MDI requires special precautions as the hardened adhesive can expose people to health risks.

Epoxy adhesive

Epoxy adhesive is an insoluble, crosslinked thermoset bicomponent polymer based on an epoxy resin and a curing agent. The properties of the cured epoxy adhesive depend on the type of hardener and the curing temperature. The advantages of epoxy adhesives are their good chemical heat resistance.

Epoxy adhesives are currently most frequently used for fiberglass reinforcements of e.g., wooden boats and glulam. Their advantages are strong bonds with the wood and higher durability than e.g., PF, while being relatively easy to work with. The disadvantages are that the epoxy adhesives are quite expensive and have long curing cycles.

Bio-based adhesives

These adhesives are thus produced from biomass instead of fossil raw materials. Common adhesives in this category are adhesives from the plant kingdom, such as starch-based adhesives for use in wallpaper adhesives, all kinds of paper products and furniture.

For construction products such as fiberboard and plywood, bio-based components have been developed that replaces large parts of the phenol in the PF adhesive. It can be made from soy protein, but in recent years lignin-based adhesives have also been introduced on to the market. A tree consists of just over 25% of lignin and is thus available in large quantities at low cost as a by-product in pulp production. It can be extracted and converted into a binder in the PF adhesive in combination with phenol, formaldehyde and isocyanate to meet the functional requirements for building materials. At present, half of the phenol can be replaced. Research is underway to gradually increase the element of lignin.

Adhesive from hemicellulose is under development at KTH, but at present (time of writing) there is no such adhesive on the market.

Tannins from bark also occur as binders in adhesives, but to a modest extent as the availability is limited.

4.2.3 Patent

To investigate which companies that have patents in bio-based adhesives, a search was made in the patent database Espacenet for relevant keywords.

The keywords used were as follows:

Keywords	Number of hits
Biobased+adhesives	892
Bio based+adhesives	202
Biobased+adhesives+plywood	78
Ligninbased+adhesives+plywood	7
Lignin based+adhesives+plywood	182

Subsequent restrictions were made to only include patents published in Europe for the past 10 years.

Results

Companies that occur most frequently as patent holders are UPM Kymmene and StoraEnso. Individual patents are also available from Foresa Industries (Spain), Abengoa Bioenergy (Spain) and Furanix Technologies (NL).

4.2.4 Input from the market

Interviews

Participating parties in the project have been interviewed about various issues such as how they experience the demand for bio-based adhesives, what obstacles and challenges exist, and what assumptions can be made about the future.

The companies are AkzoNobel, IsoTimber, Moelven, Riksbyggen, StoraEnso, Södra and Vattenfall. During the execution of the work, more actors have been identified as interesting for a more limited interview. This category includes Derome, RIGA Wood, Sika Sverige, SVEFF (Swedish Paint and Adhesive Entrepreneurs), TMF (Wood and Furniture Companies) and Vasakronan.

Most people experience a weak demand of the market for bio-based adhesive products, but it does occur, especially from the consumer market in Scandinavia. Many believe that demand will increase within a year or so as the National Board of Housing, Building and Planning requires a climate declaration for new buildings starting from 2022. In a climate declaration for buildings, it becomes clear that wooden buildings also cause CO_2 emissions. These are then mainly related to the fossil substances present in the building, including adhesives.

A concrete example is a plywood board. It consists of 7% adhesives the rest is wood. Despite this, the glue accounts for about 75% of the fossil CO_2 emissions for a plywood board. A climate declaration would make this situation visible and thus lead to increased insight from the customer to demand lower climate footprints for the next building, which leads to an increased element of bio-based substances, e.g. bio-glue.

The focus is primarily on phasing out hazardous chemicals in the adhesive, such as formaldehyde, which is highly carcinogenic. This is especially true in the furniture industry where bio-based adhesives are almost a non-issue.

End users such as real estate companies believe that they are ready to demand such products if they know they exist and if the function is the same. This strengthens the argument for the need of communication through the whole value chain.

When asked what drives the demand that even though exists today, the answer is that it is partly to increase the share of renewables in the product, but also to lower its carbon footprint. As it is easier to measure the proportion of renewable raw material in the product, this is what many initially starts with, but more and more industries are placing increasing emphasis on the carbon footprint. Several emphasize the importance of an EPD (Environmental Product Declaration), which makes it easier for

a fossil product to be easily replaced with a renewable one, which then immediately provides an answer to how the carbon footprint changes.

The EPD for plywood board shows that over 70% of the carbon dioxide emissions come from the adhesive, even though it only makes up 7% of the plywood board.

Lignin-based adhesive is available on the market which is 30-50% renewable, but so far only applied to plywood products. Continuous work to increase the proportion is ongoing.

Obstacles
The EU regulations for the RED II-directive needs to be clarified. It is difficult to invest as you do not know how the market will act.

Price, investments in machines at the customers

Performance, function, availability. The adhesive should not be worse than what you are already using.

Long certification process for adhesives for load-bearing structures such as CLT (KL wood).

Challenges
Higher proportion of renewables in the adhesive often leads to setbacks and retakes.

Difficult to maintain a consistent quality in the adhesive with an increased proportion of biobased.

SVCO Workshop Adhesives

The participants in the workshop for adhesives were Vattenfall, Södra, StoraEnso, Latvijas Finieris / RIGA Wood, Moelven, IsoTimber and Riksbyggen.

Before the workshop, the participants had worked through the tool and answered the question about how they would be affected or affect a change to "100% bio-based components in adhesives by 2030". During the workshop, the results obtained were presented and the participants were given an opportunity to develop their thoughts to increase the understanding. Subsequently, various solutions were discussed, which the participants then afterwards voted on. A summary of results can be found in Appendix 2.

The outcome shows that everyone makes the assessment that a switch to bio-based adhesives has a positive impact on the environment in general. On the other hand, some are neutral if it leads to any improvement in the quality of air and water. Solutions that facilitate this transition are believed to be a digitization of the EPD (Environmental Product Declaration) and an increased understanding of how a larger production volume of bio-based adhesives affects energy consumption.

Regarding the economy, it is believed that costs will increase before everything works reliably, but that it will contribute to increased sales. Solutions to achieve the goal are if the product can be valued higher based on sustainability and social aspects. A

proposal to reach that, a proposal that many supports, is an EPD that demonstrates the climate benefits so that it becomes credible and defensible.

Regarding social impact, the participants are either positive or neutral, where many believe that it will have a positive impact on the work environment, health and safety. It can also have a positive effect on hiring labour. A solution that is proposed is to get an increased understanding of the impact would be on the working conditions if a larger production volume would be implemented.

4.2.5 Market study

Market description

The global market for adhesives and sealants was worth 54.5 billion euros in 2018 and is expected to grow annually by about 5% until 2025. Europe had a share of 31%. The European adhesives and sealants market are currently worth more than 16.8 billion euros. In Europe, Germany is the largest producer and consumer of adhesives, with many large companies being present in the country[12]. The German adhesive industry ended the 2018 financial year with a sales increase of 3% and thus a total sale of approximately 4 billion euros. With a produced quantity of 955,000 tons of adhesive, the German adhesive industry exceeded the previous annual production by 2%. The product groups of adhesives based on natural polymers (8%) and of other adhesives (21%), achieved particularly good results[13]

In total, 830,000 tons were consumed in the EU, where the Nordic countries accounted for 8%. Of the Nordic countries, Sweden accounts for the largest part with 3.1% and Denmark for the second largest with 1,8 %[11].

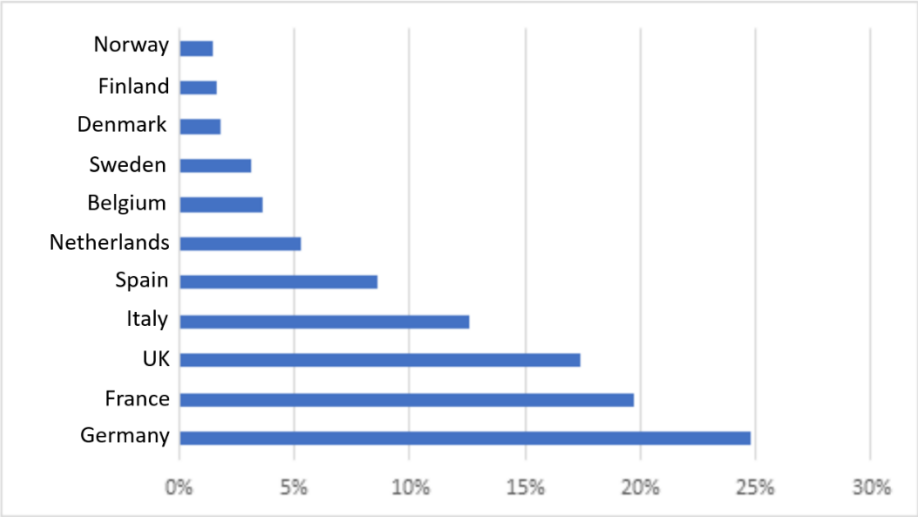


Figure 6. Adhesives consumption in Europe for 2018 (Garside, 2019)

[12] Garside (2019) Major adhesives and sealants companies revenue 2018 | Statista, Statista. Available at: https://www.statista.com/statistics/531820/adhesives-and-sealants-companies-revenue/ (Accessed: 24 June 2020).
[13] Vincentz (2019) 'Deutsche Klebstoffindustrie mit verlangsamtem Wachstum', 49(November), p. 30175.

Swedish market

In terms of sales, 28,000 tons of adhesives were sold in Sweden in 2016, distributed in three markets; Construction and handcrafts, Sealant and Industrial Adhesives, where the largest share was Industrial adhesive with 52%. Construction and handcrafts corresponded to approximately 35% and sealant for the remainder[14]

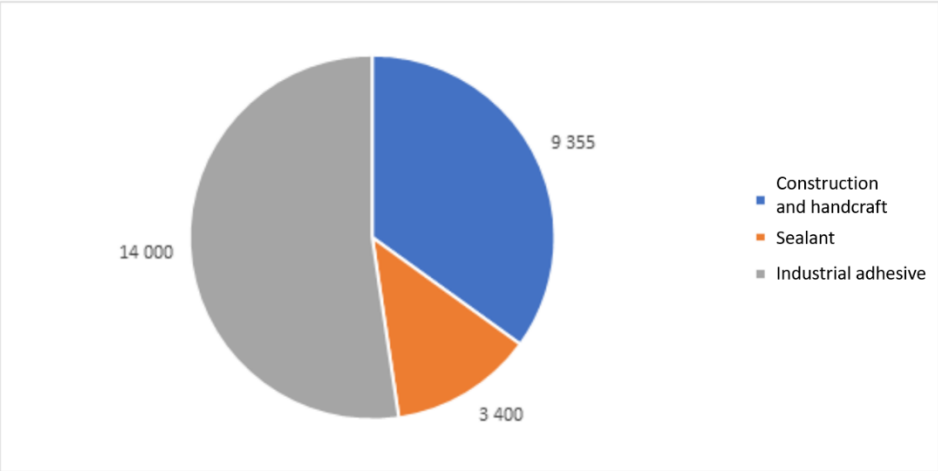


Figure 7. Sales of adhesives in Sweden for 2016 (tons)

For the category adhesives for Construction and handcrafts, you can divide the sale further, namely Floor adhesives, Wall adhesives, Mounting adhesives and Other. The subgroup Other includes wood adhesives and contact adhesives.

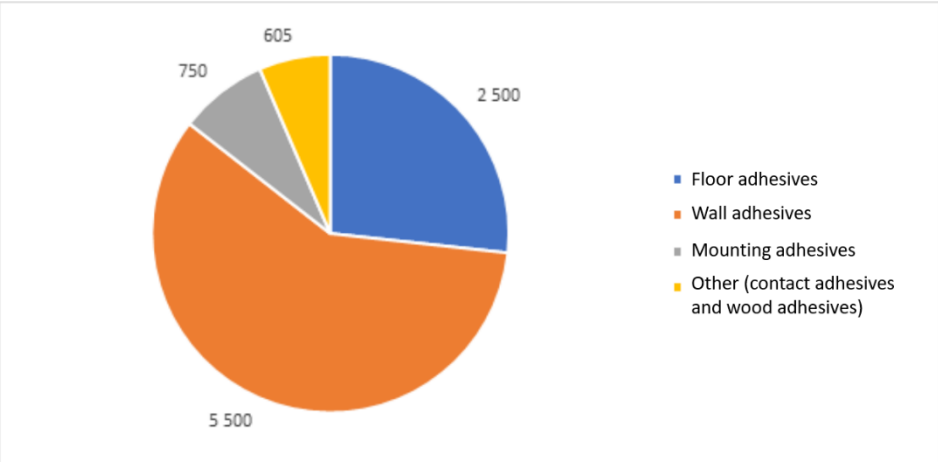


Figure 8. Sales adhesives (tons) for category Construction and handcrafts for 2016 (Jansson, 2019)

A total of 9,355 tons of adhesives were reported to the subgroup Construction and handcraft. The largest and most significant group here was Wall adhesives, which

[14] Jansson, E. (2019) *SVEFF - Sveriges Färg och Lim Företagare*

accounted for approximately 60% of sales. The mixed group Other accounted for a significant part, corresponding to approximately 6% of total sales[13].

Bio-based adhesive market

In Europe, Germany is also the largest consumer of bio-based adhesives, with many large companies having their presence in the country. The country is also a major producer of natural rubber and starch adhesives from a global perspective, which it has strengthened by increasing the production of bio-based label adhesives. In Italy, the market for modular construction is expected to grow at a significant rate in the next few years, with an increase in residential construction activities which in turn will increase the demand for good durable and non-toxic adhesives[11].

Packaging and paper were the leading application in the bio-adhesive market, with a revenue share of 36% in 2014. Bio-based adhesives are found in wide applications such as laminated printing, cigarettes and filters, flexible packaging and special packaging. The growing packaging and paper industry in emerging markets in Asia and the Pacific and Latin America is expected to increase[15]

The global bioadhesive market is expected to grow from $ 5.6 billion in 2019 to $ 9.1 billion in 2024, with an average annual growth of 10%. Growth in the application industry, such as paper and packaging, construction, woodworking and medicine, is driving the global bio-adhesive market[14].

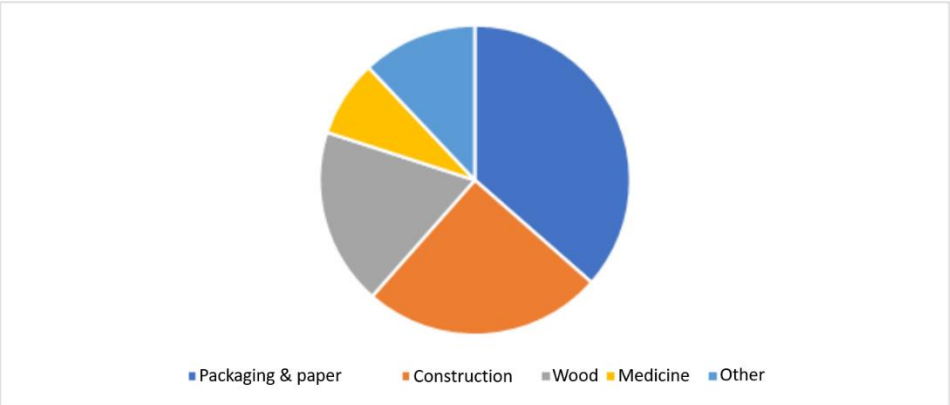


Figure 9. Global bioadhesive distribution, distributed per application (2014)

Demand for bio-based adhesives will therefore exceed market growth for conventional adhesives, especially in construction, woodworking, carpentry and all packaging segments. Soy-based adhesives are by far the market leader and replace phenolic and urea-formaldehyde adhesives in building applications.

This is still a predominantly Western European market but is starting to trend more in North America. It is also driving a boom in Asia's residential and modular construction industry with new application requirements for bio-based adhesives where delimited

[15] Markets and Markets (2019) Adhesives & Sealants Market Global Forecast to 2024 | MarketsandMarkets. Available at: https://www.marketsandmarkets.com/Market-Reports/adhesive-sealants-market-421.html (Accessed: 24 June 2020).

spaces require zero-formaldehyde emission systems and are met with high-performance bio-based adhesives[16].

Europe accounted for the largest share of the bio-based adhesive market in 2017. This can be attributed to the high demand for these adhesives in the packaging industry in various European countries, including Germany and the Netherlands. Below is a forecast for 2024.

The market in these regions is driven by growth in end-user industries, large-scale local manufacturing and the presence of a large number of domestic market players who also operate in vertical segments, such as packaging and paper, construction, wood and personal care.

Developing countries in the APAC region, such as China and India, are expected to increase demand for healthcare products due to increased awareness of health-related issues. Research and development in the medical industry has increased significantly in recent years; Awareness of the use of such adhesives in the medical application is expected to increase the demand for bioadhesives in these markets[11].

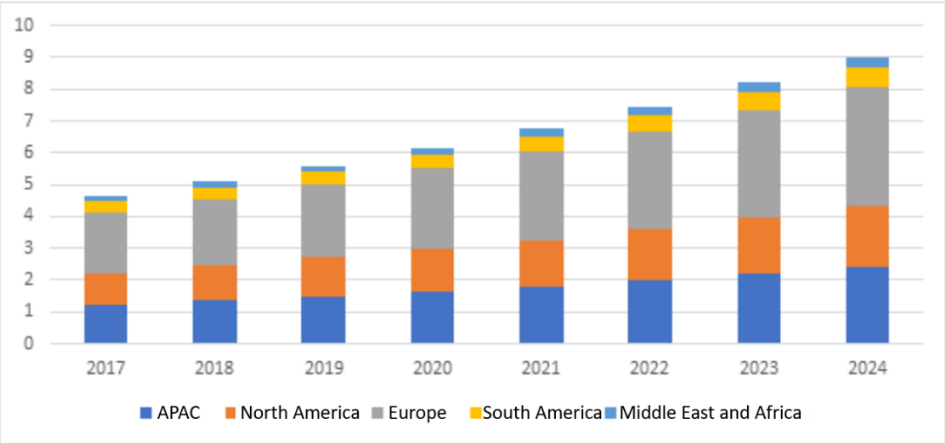


Figure 10. Bio Adhesive Market, by region (Garside, 2019)

Adhesives plays an important role in the forest industry. With adhesives, companies can refine crooked wood of different types and sizes into functional products. Most wood products today include additives, means to protect the wood against biodegradation, against fire, to give the wood a better aesthetic appearance, to improve the product's performance and to overcome weaknesses in the wood material or to combine wood residues with plastic to create new types of composites. The adhesive can in some cases also increase the qualities of the material, for example the stiffness and resilience of the composite board.

[16] Cullinan, B. (2020) *Interview: "Adhesives are becoming the preferred method of bonding" / Markets & companies - European-coatings.com*. Available at: https://www.european-coatings.com/Markets-companies/Interview-Adhesives-are-becoming-the-preferred-method-of-bonding/(language)/eng-GB (Accessed: 24 June 2020).

In Swedish wood production, it is the increased domestic consumption of, for example, wood floors that has increased the production of adhesives for the wood industry. Since 2016, it has increased by 15%, when exports are approximately the same and imports have also decreased by 20% since 2014. The largest exports of Swedish wood products go to Germany[17]

The wood adhesive market is expected to grow to a significant average annual growth of 4.5% as the scope and its applications increase enormously worldwide. Growth in the renovation industry, development of construction, furniture and woodworking activities and growing urban populations are documented as important factors for the wood adhesive market. The global wood adhesive market is expected to reach $ 6.2 billion by 2025[14].

Adhesive manufacturer

The most important players in the global adhesive manufacturing market are Henkel AG & Co, 3M Company, Sika AG, Wacker Chemie, HB Fuller and Avery Denisson. In the Swedish market are 3M, Akzo Nobel Adhesives AB, Beardow Adams AB, Bostik AB, Danalim A / S, Dural Gmbh, Essve Produkter AB, Henkel Norden AB, Mapei AB, Saint-Gobain Sweden AB, Savotech AB, Sika Sverige AB, Simfas AB and Tremco-Illbrück AB[12].

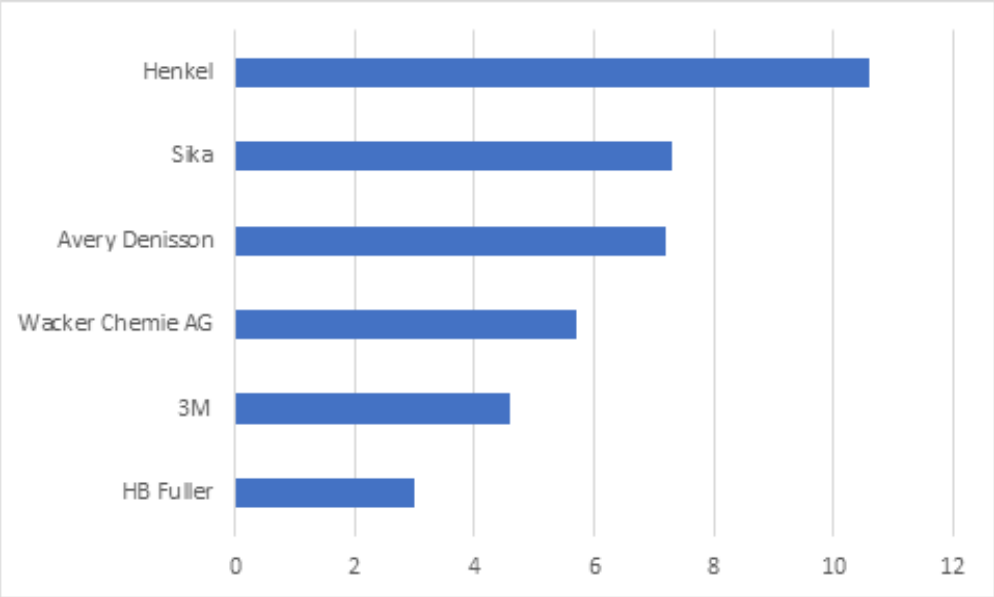


Figure 11. Companies with the largest revenues from adhesive production (2018) (Statista, 2019)

The bio-based world adhesive market is mainly dominated by companies such as Henkel AG & Co. EcoSynthetix Inc., Paramelt BV, 3M Company, Adhesives Research Inc., and Yparex BV. These companies develop niche application products to maximize their product penetration in a variety of industries.

[17] TMF (2019) *TMF i siffror, statistik om svenska träindustrin*. Available at: https://www.tmf.se/siteassets/statistik/statistiska-publikationer/tmf-i-siffror/tmf-i-siffror-1-2018.pdf.

When it comes to lignin adhesives, there are several lignin adhesives that have been tested on an industrial scale in the USA, Finland and New Zealand (Ligate). Some concrete examples are UPM, which manufactures the WISA BioBond adhesive used in their manufacture of plywood boards. StoraEnso also extracts lignin under the LINEO brand, which is sold as a binder to adhesive manufacturers, including the Latvian company Latvijas Finieris, which uses the adhesive RIGA ECOlogical in their production of birch plywood.

Plywood made with lignin adhesive by UPM and Latvijas Finieris is available on the market. The same applies to products with soy protein adhesive from the USA (SoyBond and Soyad).

3M has developed an adhesive that consists of 67% plant-based adhesive and 100% recycled material. However, it is currently only used to hold up post it notes, so it is not that strong. 3M is investing more and more in sustainability, so every new product that comes in must, according to the company, have a sustainability promise[18]

Beardow Adams AB has developed an environmentally friendly hot melt adhesive - BAMFutura - which has already proven successful with several large food and beverage manufacturers. This product is an approved packaging adhesive that works well for packaging and carton seals[19].

EcoSynthetix is a renewable chemical company that specializes in biomaterials used in various end products, including an adhesive that they have based on sugar-acrylic. As part of their business, they also offer their services to support their customers in the transition to becoming more sustainable and reducing their climate footprint on a broad front[20]

United Soybean Board and Columbia Forest Products have together created PureBond a durable, plywood panel made with soy-based adhesive. Basing the adhesive on soy made it possible to replace formaldehyde. American soy is now available in 100 million plywood panels by PureBond, 20 million m3 OSB (Oriented Stranded Board) and is also used by manufacturers for cabinets and furniture. The disadvantage of soy adhesive is the sensitivity to moisture, which makes it suitable for products used indoors. There are also green benefits that come from the use of soy flour because MDI is hydrocarbon based[21]

In 2017, Prefere became Europe's first manufacturer to replace a large amount of phenolic content with lignin. Prefere is a multinational adhesive manufacturer that is

[18] Johansson, D. and 3M (2020) 'No Title'.
[19] Beardowadams (2020) *The Environment | Hot Melt Adhesive | Beardow Adams*. Available at: https://www.beardowadams.com/our-policies/the-environment (Accessed: 13 July 2020).
[20] Ecosynthethix (2020) *Choose Biopolymers to Reach Sustainability Goals | EcoSynthetix*. Available at: http://ecosynthetix.com/improve-sustainability (Accessed: 13 July 2020).
[21] ASI industry (2020) *Performance and Sustainability: Soy-Based Adhesives and Sealants Excel in Wide-Ranging Applications | 2020-05-13 | Adhesives & Sealants Industry*, *2020-05-13*. Available at: https://www.adhesivesmag.com/articles/97755-performance-and-sustainability-soy-based-adhesives-and-sealants-excel-in-wide-ranging-applications (Accessed: 13 July 2020).

the leading European manufacturer of thermosets. They have recently acquired INEOS Melamines & Paraform and created three new business units (Prefere Phenolic, Prefere Melamines and Prefere Paraform), which has led them to grow in a relatively divided market where the top 10 leading players have accounted for only 25% of the market[22]

Henkel uses renewable materials such as starch, cellulose and proteins in their products, such as adhesive sticks, wallpaper paste and packaging. Adhesives used for bottle labels contain, according to the manufacturer, as much as 45% renewable raw materials[23]

Based in Columbus, Ohio, Hexion is one of the leading companies in thermal resins and offers thermoset adhesives to the global wood and industrial market. They are also developing a new phenolic resin technology that will replace phenol with lignin in the production of wood panels[24]. In 2019, it was announced that Hexion was about to go bankrupt, but by signing a new restructuring agreement with its financiers, they were able to reduce their debt by $ 2 billion and inject $ 300 million in new capital to continue financing the business[25].

H.B. In Nov-17, Fuller opened its new "Automotive Competency Center" in Mannheim, Germany. This centre expands H.B. Fuller's ability to develop and manufacture sustainable smelting, water-based, solvent-based, reactive and film-adhesive technologies for various vehicle, construction, electronics and electric vehicle and battery applications. According to the company, new application machines, test equipment, laboratory functions and space facilitate expanded customer engagement in innovation, including concepts, prototypes and final design[11].

BioTAK has developed a completely biodegradable adhesive, specializing in complementing compostable packaging and products. According to the manufacturer, the adhesive is waterborne and suitable for lamination, e.g. create bioplastic films or compostable fruit labels[26].

Research and progress

SUSBIND is an international research project that plans to develop, produce and test bio-based adhesives to eventually release formaldehyde resin. They plan to use the adhesive for wood-based panels in furniture production and produce these together

[22] Prefere (2019) *Acquisition of INEOS Melamines & Paraform - News - Company - Prefere Resins*. Available at: https://prefere.com/en/company/news/acquisition-of-ineos-melamines-paraform (Accessed: 19 August 2020).
[23] Henkel (2018) 'Sustainability Report Henkel', *State-Owned Enterprises and Corruption*, pp. 15–18. doi: 10.1787/9789264303058-4-en.
[24] RISI Technol (2018) *Hexion Specialty Chemicals | RISI Technology Channels*, *2018*. Available at: https://technology.risiinfo.com/company/hexion-specialty-chemicals (Accessed: 19 August 2020).
[25] Tullo, A. (2019) 'Hexion files for bankruptcy', *C&EN Global Enterprise*, 97(14), pp. 12–12. doi: 10.1021/cen-09714-buscon3.
[26] Biotak (2020) *compostable adhesive - BioTAK® - biodegradable adhesive*. Available at: https://biotak.eu/ (Accessed: 13 July 2020).

with some companies that produce chipboard and medium density fiberboard (MDF). According to the research group, the forecast is that they will surpass the current conventional adhesive systems with the help of a significantly lower carbon footprint and at the same time reduce emissions that are toxic to humans[27].

Piperonal, made from black pepper and castor oil, is another commercially available bioadhesive and is produced on industrial scales. Researchers from the POLYMAT Institute at the University of the Basque Country have designed a new PSA made from 71% renewable biological products. The adhesive can be adjusted to different strengths with the help of ultraviolet light according to the manufacturer can be easily adapted in conventional existing production facilities. They also succeeded in synthesizing the adhesive in water, which according to the research group minimizes volatile organic compounds, improves the overall safety of the process and reduces costs[28].

Boston University has found a biodegradable adhesive that is made entirely of naturally derived chemical components. The research team behind the innovation says that the adhesive's formula is easily adapted to suit a wide range of industrial and medical applications that benefit from sticky materials[29].

In Sweden, research is underway with the development of adhesive from hemicellulose (KTH) in order to be able to contribute to a bio-based adhesive from forest raw material starting to be manufactured / developed in Sweden within a few years. The challenge is that the new adhesives, with good competitive economy, efficiency and a sufficiently fast process, could meet the same requirements as synthetic adhesives[30].

The Finnish company Kiilto has developed a hot melt adhesive that enables the production of fully compostable packaging. A biodegradable adhesive that can replace the usual hot melt adhesives that are manufactured, for example from oil-based raw materials in various applications in the packaging industry and in the manufacture of hygiene products. The other properties of this biodegradable adhesive are the same as those of hot melt adhesives currently on the market. But what stands out is its environmental performance, and that it is biodegradable[31]

[27] BBI-europe (2020) *SUSBIND | Bio-Based Industries - Public-Private Partnership*. Available at: https://www.bbi-europe.eu/projects/susbind (Accessed: 13 July 2020).

[28] Badía, A. *et al.* (2019) 'UV-Tunable Biobased Pressure-Sensitive Adhesives Containing Piperonyl Methacrylate', *ACS Sustainable Chemistry & Engineering*, 7(23), pp. 19122–19130. doi: 10.1021/acssuschemeng.9b05067.

[29] Beharaj, A. *et al.* (2019) 'Sustainable polycarbonate adhesives for dry and aqueous conditions with thermoresponsive properties', *Nature Communications*. Nature Publishing Group, 10(1), p. 5478. doi: 10.1038/s41467-019-13449-y.

[30] RISE (2018) 'Lim och färg för en fossilfri byggd miljö Slutrapportering Steg 1 Initiering', 1(10), pp. 1–10.

[31] Kiilto (2020) *Biodegradable hot melt adhesive makes for environmentally friendlier packaging*. Available at: https://www.kiilto.com/en/newsroom/news/biodegradable-hot-melt-adhesive-makes-environmentally-friendlier-packaging (Accessed: 13 July 2020).

Customers

The wood industry

The global wood industry is by far the largest user of adhesives; about 80% of all wood and wood-based products involve some form of adhering and 70% of the total volume of adhesive produced is consumed in the woodworking industry. The business also has traditions that most other adhering processes do not have. The objects to be adhered are relatively large and wood can thus be considered as a composite consisting of wood-based materials combined with other materials to form an aggregate material.

An example is plywood, where veneers are joined with adhesive to form a flat panel. In plywood production, PF adhesive (phenol / formaldehyde) is mainly used as a binder, which provides moisture-resistant adhesive joints. Plywood intended for indoor use, often deciduous wood plywood, can be adhered with UF adhesive.

Fibreboards can have sawdust, cutter shavings, pulpwood or softwood as a starting material. A common disc is so-called MDF (Medium Density Fiberboard). A common adhesive is UF adhesive, but others can also be used. Particleboard consists of wood chips that are adhered together with UF adhesive.

It is difficult to determine with certainty the use of adhesives in Europe. Estimates suggest that the use of adhesives for particle board is divided between UF (92%), MUF (7%) and isocyanates (1%). OSB is mainly made with polymeric phenylmethane diisocyanates (75%), while UF (10%) and MUF (15%) are also used[32].

In glulam, Austria is the largest producer in Europe with around 1.8 million m3 of laminated timber per year (2018), which is an increase of 0.3 million m3 in three years. Much of it is exported, both as glulam and CLT (Cross Laminated Timber), where the majority (650,000 m3) ends up in Italy or Germany[33]

The global CLT market was valued at $ 603 million in 2017 and is forecast to reach 1.6 billion in 2024. Overall, Europe's share of the global CLT market was approximately 60% in 2018, with most manufacturers in Germany, Austria and Switzerland. If you look at the forecast for 2020, 70% of production is in the DACH countries, 16% in the Nordic countries (of which 40% are represented by Sweden) and the remaining 14% in France, the United Kingdom and Italy[34]

According to the standard SFS-EN 16351, three different types of adhesives can be used, polyurethane adhesives (PUR), EPI and MUF adhesives in the manufacture of

[32] Vnučec, D., Kutnar, A. and Goršek, A. (2017) 'Soy-based adhesives for wood-bonding – a review', *Journal of Adhesion Science and Technology*. Taylor & Francis, 31(8), pp. 910–931. doi: 10.1080/01694243.2016.1237278.

[33] Skogsindustrierna (2019) *Så går det för skogsindustrin*. Available at: https://www.skogsindustrierna.se/siteassets/dokument/sa-gar-det-for-skogsindustrin/sa-gar-det-for-skogsindustrin-februari-2019.pdf.

[34] Danske Bank (2019) *Skog och ekonomi*. Available at: https://danskebank.se/-/media/files/se/pdf/skog-och-lantbruk/skog-och-ekonomi-nr-4-2019.pdf.

CLT. Of these three, formaldehyde-free polyurethane adhesive is the most common among CLT manufacturers[35].

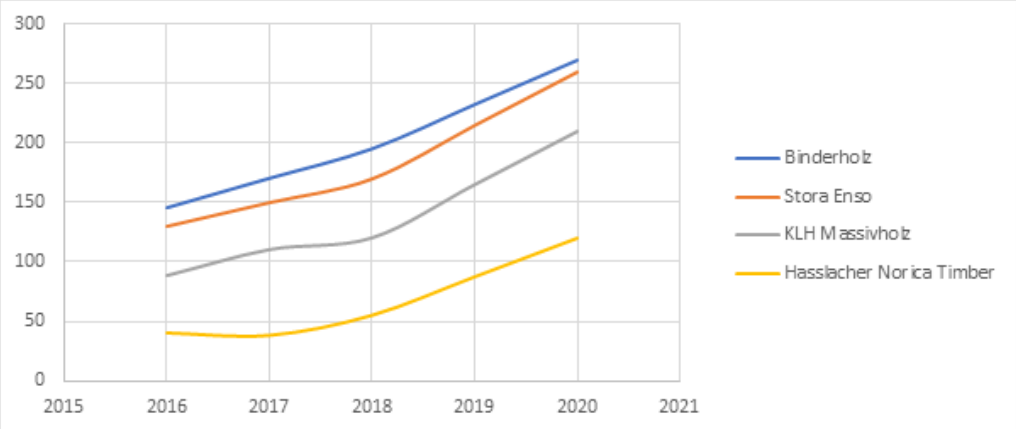


Figure 12. CLT production in Europe (1,000 m^3/år)

In Russia, the Segezha group has begun work on the first CLT plant in the country. The group has invested almost $ 48 million in the plant, which will have a capacity of approximately 250,000 m3 of CLT panels per year. In North America, the United States accounts for the largest production with 432,000 m3 compared to Canada's 34,000 m3 (2018). Production has been relatively stable during the period 2016 - 2018[36].

The car industry

In 2030, it is estimated that the number of electric cars can amount to 220 million. Adhesives are expected to play a crucial role in the manufacture of electric vehicles as they enable the gluing of various materials. Adhesives are already widely used in the automotive industry, for example for thermal conductivity and handling and corrosion protection. The expected large demand for electric vehicles is predicted to open a new path for industrial adhesives.

The car industry has a broad business. Ceilings and other interior panels are often laminated to a preformed surface. The adhesive used is usually polyurethane rubber adhesive with solvent, usually with the addition of isocyanates. Installation of carpets and panels takes place via a self-adhesive material. For mounting details to the interior, hot-melt adhesive is used on a polyurethane base (with isocyanates) which is applied at a temperature of 100 degrees and a risk of isocyanate escaping arises. When joining body parts (in connection with spot welding), PVC plastisols are applied. These are then gelled in the paint ovens at the same time as the paint has dried out[37]

The aviation industry

[35] Oscarsson, J., Blixt, J. and Ab, V. (2016) 'Förutsättningar för produktion av CLT i södra Sverige'.

[36] Timber online (2018) *Plans for CLT*. Available at: https://www.timber-online.net/holzprodukte/2018/06/plans-for-clt-factory-in-russia.html.

[37] Business Insight (2020) *Adhesives & Sealants Market Size to Reach USD 66.76 Billion by 2026; Rising Demand for Mobile Devices to Prove Favorable for the Market, Says Fortune Business Insights™*. Available at: https://www.prnewswire.com/in/news-releases/adhesives-amp-sealants-market-size-to-reach-usd-66-76-billion-by-2026-rising-demand-for-mobile-devices-to-prove-favorable-for-the-market-says-fortune-business-insights-tm--840260534.html (Accessed: 24 June 2020).

The aviation industry has been heavily dependent on adhesives. The adhesives used for aircraft adhering are mostly in film form ("pre-preg"). Nowadays, they all usually have an epoxy base, which can be modified with phenol or rubber. Two-component epoxy adhesives and anaerobic adhesives are also used to some extent.

The aviation industry may be considered to have a special position in terms of gluing. Where other industries have tried to avoid gluing if work environment problems have arisen, the aviation industry has tried to learn to master the problems and develop methods that protect employees from the risks.

The electronics industry

The electronics industry includes the manufacture and assembly of electronic components, where several components must be adhered because they cannot withstand soldering temperatures. In the electronics industry, the adhesives are "many but small". Among other things, cyanoacrylates, anaerobic adhesives, epoxy adhesives and UV-cured adhesives were used.

The construction industry

The construction sector contributes to large emissions of greenhouse gases. There is a lot of pressure on this sector to reduce its climate impact. Building more in wood has been identified as a very effective way to reduce greenhouse gas emissions. For many companies that use and develop building materials in wood, good environmental and climate properties are part of their profile. There is thus a demand, especially from these players, for bio-based adhesive and paint components. At the same time, there are demands on the performance and usability of these products, which must live up to the standard of modern, conventional products.

Market forces

Opportunities / Driving forces

The bio-based adhesive market is primarily driven by advances in technological innovations, increased marketing and an increased public debate. Technological innovations, as well as research and development (R&D) in the biotechnology industry are expected to continue to support the production of naturally produced adhesives. The advances in manufacturing technology that are now being made aim to improve the mechanical and chemical properties of the adhesives, which is expected to contribute to great growth opportunities for the players operating in the bio-based adhesives market.

The benefits of environmentally friendly adhesives are being marketed more and more, which helps to improve the performance of the adhered product in addition to its properties such as durability and elasticity.

There are industry organizations that label more environmentally friendly adhesives to clarify the benefits of using biological adhesives. One such is EMICODE - an EU-based system developed by the German adhesive industry in the late 1990s that represents a labelling system with "low-emission" construction adhesives and related products.

EMICODE is basically the only label for adhesives that works throughout Europe that is highly recognized by construction professionals. The EMICODE system is maintained by GEV, a low-budget / non-profit industry organization consisting of participating companies[38].

It is clear how environmental regulations, both in the work environment but also laws and regulations created to prevent fossil-based use, have a very positive effect on growth in the bio-based adhesive market. There is strong support from the EU's policy for sustainable and circular development.

The increasing demand for wood-based products results in increasing revenues, which in turn strengthens the demand for bio-based adhesion products globally. Demand for lighter vehicles, more environmentally friendly buildings and packaging also continues to drive growth in bio-based and healthy adhesives. Adhesives are increasingly replacing mechanical fasteners for all types of devices and are increasingly becoming the preferred method of joining[15].

There are also several advantages to an integration between the production of adhered wood components and other forest industry, which provides the raw material. Products with bio-based adhesives that are now starting to reach the market are, for example, plywood adhered with lignin adhesive, where the lignin is extracted, converted into adhesive and used for adhering plywood within the same group. This reduces the market risk for the lignin adhesive. Adhesives for glued wood components, such as wooden boards, glulam and cross-glued wood thus have great potential, but niches for introducing new products need to be chosen with care to match the quality requirements.

This is still a predominantly Western European market but is starting to trend more in North America and Asia. Pursuing new application requirements with bio-based adhesives is increasing more and more in Asia's housing, modular construction industry. The problem of confined spaces that require zero emissions of formaldehyde is potentially seen to be solved with high-performance bio-based adhesives.

Market barriers

The bio-based adhesive market is mainly hampered by the low use of biologically produced adhesives in some industries due to the low shelf life of these materials and their high substitution with conventional adhesives on the market. The players in the various industries need to feel reliable about the product before they can start investing and using it.

Laws and regulations are largely an enabler. But there is also a great risk, for example regarding lignin adhesives. Many adhesive manufacturing processes are protected by extensive patents in other countries (USA, Finland), which makes it difficult to develop a new lignin adhesive with a high TRL in a short time. This does not apply to

[38] EMICODE (2020) *EMICODE - About*. Available at: https://www.emicode.com/en/home/ (Accessed: 24 June 2020).

hemicellulose adhesives as this invention is already protected in Sweden and is owned by researchers at KTH, so it is estimated that this adhesive has the potential to be included in pilot scale experiments in the near future.

Adhesives from renewable resources are, however, of interest, not least for environmental reasons, but few have been able to influence the market by showing strong competitiveness in both good performance and low production costs. For example, joining different composite materials and metal materials is still a major challenge due to the need to achieve both bond strength and thermal expansion.

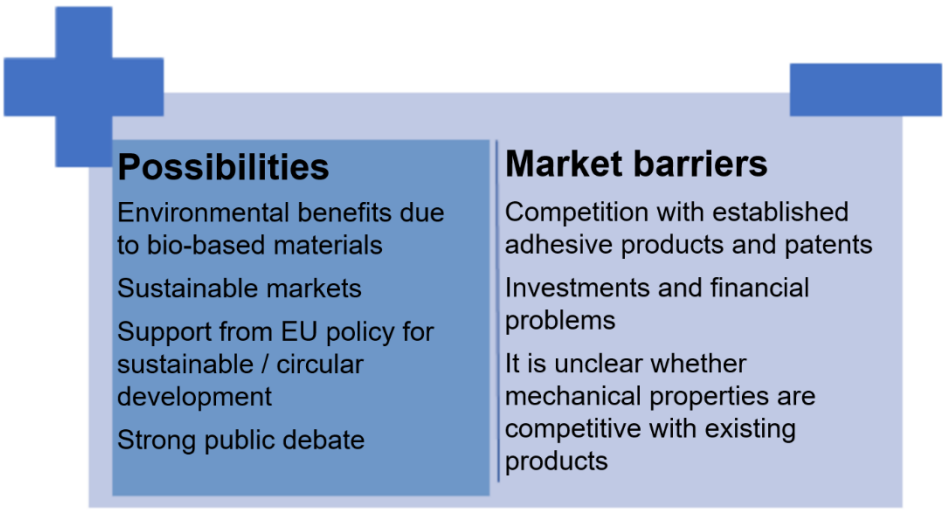


Figure 13. Opportunities and market barriers

4.2.6 Cost estimate

The project includes an estimate of how an increased cost to produce bio-based adhesives affects costs further down the value chain.

Manufacturers of plywood boards believed that if a bio-based adhesive were to be twice as expensive as a conventional adhesive, it would entail an increase in cost of 8% on the plywood board.

The lignin-based adhesives that are now on the market are stated to be a maximum of 10% more expensive than conventional adhesives. This would then mean that the cost of a plywood board with such an adhesive would be almost 1% higher.

There are also examples of adhesive manufacturers (Latvijas Finieris / RIGA Wood) who have chosen not to pass on the costs in the value chain. The customer must receive a product with a lower carbon footprint at no increased cost.

4.3 The methanol market

The project included, as far as the budget allows, also investigating the methanol market and other possible value chains other than as a basic molecule for components used for Adhesives and Paint. The resources for the project have mainly been used for the main question, i.e., bio-based components for Adhesives and Paint, so a very limited interview has been conducted with BASF as a first insight into a market analysis.

BASF primarily produces methanol from methane in its own process, which means that it sees methanol as step 2 in the internal value chains. Methane is a cheap raw material, and it is therefore difficult to compete with price compared to methanol produced in this way. BASF also buys methanol, then mainly fossil-based, but again it becomes a price and volume issue, as BASF, and other large chemical companies, need large quantities to be able to start production. BASF says that you need> 50 ktons of Methanol for it to be interesting.

There are many potential value chains for methanol, but the large volumes go in addition to adhesives and dyes for textiles and polymers via steps such as formaldehyde and butanediol.

An interesting way, according to BASF, to increase the supply of bio-based methanol is the activities that are taking place right now such as. Vattenfall's activities in the hydrogen area, but Södra's initiatives are also mentioned as interesting, but still on a comparatively small scale.

5. Conclusion

In order to gain an understanding of how costs are propagated in reality, it is of the utmost importance to carry out a value chain analysis where you have representation from the various actors in the chain. By having a well-composed group, you can also discuss solutions for how to overcome the obstacles that exist, real or experienced, and thus be able to change more quickly in a way that benefits all parties.

For both paint and adhesive there is a common picture among the players that the higher cost of bio-based raw materials is an obstacle to a change. The project has shown that for both categories, the price increase, theoretically calculated, is not so great in the end, which would suggest that price is not the big obstacle. It seems rather that the obstacles are a lack of knowledge about bio-based alternatives among decision-makers and thus a weak demand.

At the same time, it is clear that those who are early in the value chain are those who need to pay more for the “raw material”, 40-100%, and also realize large investments in their production apparatus, which will affect their profit margins. Therefore, it is important to meet across borders in the value chain to find solutions for how to overcome these economic barriers and allocate the risks. Other alternative solutions that could mitigate the consequences of an increased cost have not been studied in this project.

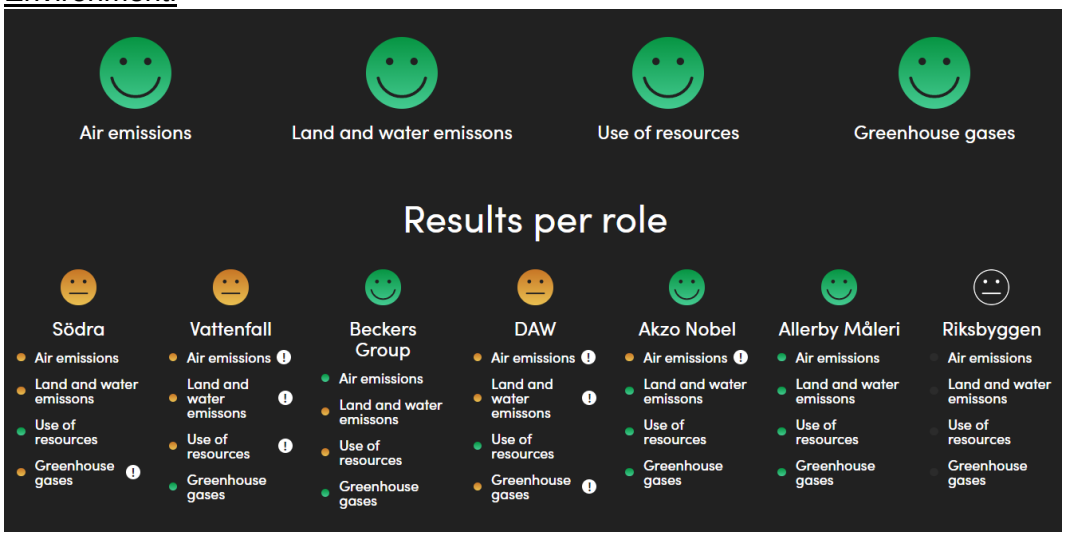
A strong driving force for conversion in addition to the desire to offer more environmentally friendly products is whether there will be demands for increased use of bio-based products, e.g., through various forms of certifications. The increased public interest in society and the ongoing debate on climate also contribute in a positive way.

6. Next steps

- Study regarding the possibility of producing the aromatic acids and solvents or alternatives to these from bio-based raw material
- Projects to create forums where knowledge of bio-based adhesives and paints or products where they are used are presented to decision-makers to accelerate the transition
- Map other value chains in the area of adhesives and paints
- Study of existing policies, regulations in the area to be able to work for new rules to drive the transition
- Study of the effect on profitability for companies early in the value chain with sharply increased raw material costs

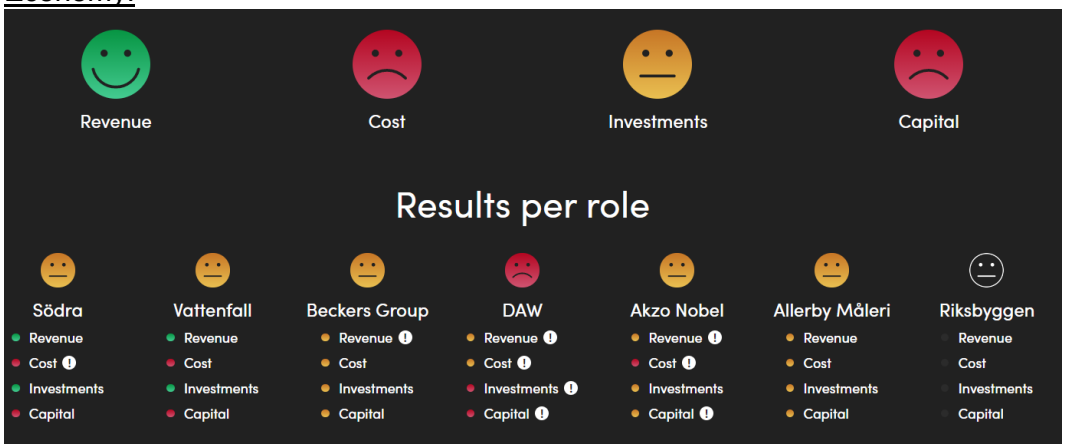
7. Appendix 1: Results SVCO-workshop Paint

Environment:



Proposed solutions, Environment	
Focus on the right products from biomass from a chemical perspective	80% (4)
Create a standard for how environmental performance is to be monitored	80% (4)
Focus on reusing residual materials for the production of new raw materials	80% (5)
Get a public metric, e.g. in annual reports – KPI, purchase of cinema in% of the total	80% (4)
Requirements for CO2 labeling, EPD labeling	100% (5)
Requirements for reporting of CO2 footprint (EPD)	100% (5)
Use the green energy that comes with resource-efficient processes	80% (4)
Focus on chemicals that come from biomass, which provide good yields and require little energy	80% (4)

Economy:



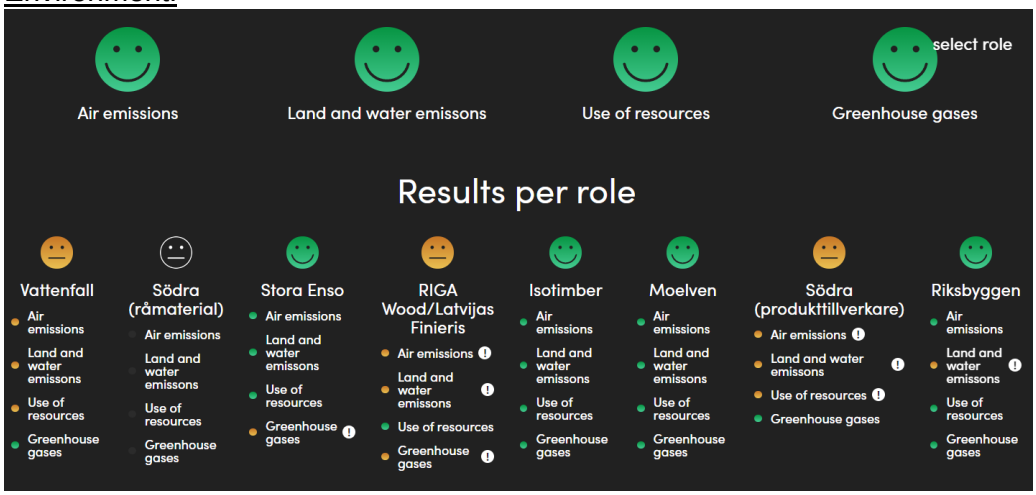
Proposed solutions, Economics	
Allow / force government organizations to prioritize environmentally sustainable alternatives in procurement	80% (5)
Create increased awareness downstream in the form of case studies and education. Engage decision makers in the construction industry.	50% (4)
Municipalities and the state need to value sustainability in procurements. Dare to choose solutions that are sustainable	70% (5)
Active collaboration with end users and end customers to get a "pull"	80% (5)
Work long-term in value chain projects	60% (4)
Work with the right customer groups - start using it and open your eyes to it - create demand	100% (3)
Engage the big contractors, consultants, architects	80% (3)
Create a common group that develops together, e.g. questions: which molecules work	60% (4)
Increase awareness of value chain partners, case studies, education	50% (3)
More technical opportunities to work with producers. Understand each other	50% (4)
Labeling and certification of end product with CO_2 profile	90% (4)
Link to construction assessments such as BREEAM and LEED in marketing and other communication	80% (3)
Find niche applications where there is a willingness to pay initially. There, the end customer values the product, and can pay.	100% (5)
Some part of the cost can be covered by the innovation authority - to justify	60% (5)
Work with the right customer groups, ie those who have an interest	100% (5)

Social:

Suggested solutions, Social	
Create systems that ensure that production does not compete with food production, does not create unfavorable working conditions, etc.	100% (5)
Any kind of 2nd life use? Because bio-based	30% (2)
Certify / origin mark bio-based raw materials to avoid negative effects on the environment and human health	70% (5)
Driving force: spread so that the benefits of change reach globally. Equality	50% (4)
Sourcing the right way. How will it be in the future with increased volumes / demand	80% (4)

8. Appendix 2: Results SVCO-workshop Adhesives

Environment:

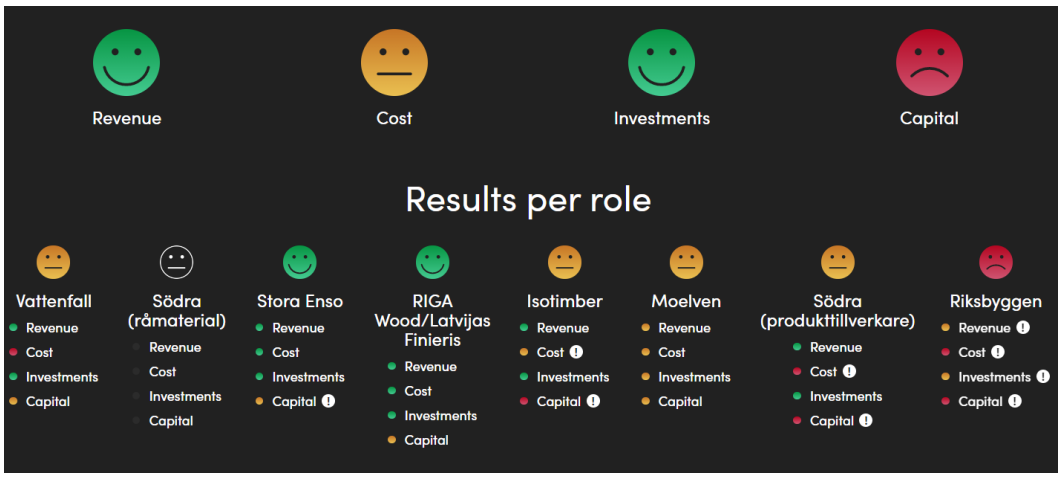


Proposed solutions, Environment	
Understand if / how increased production capacity affects energy consumption	100% (5)
Digitization of EPD	100% (5)

Comments:

- Positive for the environment to switch to more fossil-free raw materials.
- The chemicals are a small part of the product, but account for a large part of the emissions. If they can be changed to fossil-free, the emissions also go down a lot.
- It is not entirely clear what the processes look like and where the emissions take place. Those who work directly with this are aware, but the understanding needs to be raised. In some cases, more knowledge needs to be built.
- In CLT and construction, it is strength requirements that drive. Bio-based adhesives must achieve the same strength requirements as fossil-based adhesives.
- The end users point out that it does not affect them what type of glue is used, it is decided in earlier steps by eg contractors. If LCA is done over the entire chain, it is also visible to the end user.

Economy:



Suggested solutions, Economics	
Slutprodukten måste bli högre värderad, utifrån hållbarhet och social påverkan	100% (4)
Jag tror at det är viktigt att snabbt få fram en EPD så att klimatnyttan är trovärdigt bokförbar och försvarbar	100% (4)
Kan bidrag till klimatomställningen, typ klimatklivet, användas för att minska merkostnaden till slutkonsumnet?	90% (4)

Comments:

- Very neutral. Comments such as that it does not affect production in any particular direction. Investments will probably need to be made, but that will come later.
- Product manufacturers comment that it can be difficult to buy bio-based glue if it becomes more expensive. It will be more expensive according to product manufacturers. The question of how much more expensive it will be, or how much more expensive it is too much was not discussed during the workshop. Basis for continued knowledge building.
- In some stages, rebuilds will be required, especially in later stages in the value chain. Bio-based adhesives may require, for example, longer press times, which leads to a need for increased staff and increased machinery, so in the long run capital is required for investments. Unforeseen conversions difficult to predict.
- End users point out that in the long run they will want to order fossil-free products, but the price is difficult to predict as it is often determined at an earlier stage, for example by contractors. Difficult to value costs.

Social:

Suggested solutions, Social	
Understand how increased production volume affects working conditions	60% (4)
Test	100% (4)

Comments:

- Difficult to know how the work can change. Many believe that it will not change for the worse.
- Should be able to lead to safer employment when a change in the long term is necessary and when it is done, it ensures the survival of the companies and in the long run the security of the employees.
- A change can lead to an increase in the number of employees. Both due to increased demand, but also due to the fact that certain processes may require staff when switching to fossil-free.
- Even if today's chemicals are only a single per mille of the products, a transition to fossil-free adhesives will contribute to less toxic environments for the employees and those who handle the products.