Crude tall oil low ILUC risk assessment

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By: Daan Peters, Viktorija Stojcheva
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Executive Summary

UPM produces renewable diesel and naphtha from crude tall oil (CTO) in its biorefinery in Lappeenranta, Finland from early 2015 onwards. Because the company wanted clarity on the status and sustainability of its feedstock, UPM asked Ecofys in 2013 to assess whether CTO can be regarded as a residue and whether the feedstock would be low ILUC risk, meaning its use for biofuels would not lead to displacement effects of existing other uses. The current report is an updated version of the 2013 report. An important change since the previous report is that biofuel production at UPM has started, so any effects of CTO usage for biofuels has on the CTO market would be visible. Ecofys studies the following questions in this report:

1. Can CTO be defined as a residue based on biofuel legislation
2. Does the feedstock create an additional demand for land (is it a low ILUC risk feed stock?)
3. Does the use of the feedstock for biofuel production cause significant distortive effects on markets?

The second and third question are closely interlinked. CTO in itself is a non-land using feedstock. A potential ILUC risk can therefore only follow from a situation in which an increase in CTO demand would displace existing uses of the material by non-bioenergy sectors, that could in turn increase the use of vegetable oils such as soybean oil as feedstock. If the answer to question 3 is negative, then question 2 is answered simultaneously.

What is crude tall oil and what is it used for

Crude Tall Oil (CTO) is a material which is generated in the wood pulp production process. The word 'tall' is means 'pine' in Swedish, which indicates that CTO is mainly generated in the pulping of softwood (pine) trees. When pulping pine trees, a residue is generated called black liquor. Black liquor contains valuable chemicals that are fed back into the pulping process. In order to do this first a layer of soap is removed, called Crude Sulphate Soap (CSS). This CSS can either be burned as process fuel or further processed into CTO. The use of CSS as process fuel has certain limitations and therefore it often makes sense for pulp mills to process most CSS into CTO.

CTO has four main categories of uses; it can be used (1) as process fuel in the pulp mill lime kiln, (2) distilled into a variety of products, (3) used as a component of petroleum extraction drilling fluid or for phosphate mining and (4) it can be used to produce renewable diesel. By far most CTO is used as feedstock by CTO distillers. CTO is a globally traded material which is imported from the USA in considerable quantities. This means that while we're mainly interested in the EU market, the analysis in this study has a global scope.

CTO can be defined as a processing residue based on biofuel legislation

The EU ILUC Directive includes a definition of processing residue: 'a substance that is not the end product(s) that a production process directly seeks to produce; it is not a primary aim of the production process and the process has not been deliberately modified to produce it.' CTO is generated in the

process to produce pulp from softwood. The pulping process directly seeks to produce pulp, not CTO. Pulp production is the primary aim of the softwood chemical pulping process. This is underpinned by the fact that the value CTO represents only a small fraction of maximum 5% of the total value of the pulp production process. The choice between chemical pulping (which generates CTO) and mechanical pulping (which does not generate CTO) is based on the desired specifications of the pulp, not on whether it is desirable to also generate CTO and CSS, the precursor of CTO is derived as process residue in relatively fixed quantities. It is not possible to modify the process in order to yield a higher quantity of CSS at the expense of the pulp yield.

We conclude that CTO fits into the definition of process residue. Could it also be considered a co-product or a product? In literature, the material is sometimes called a co-product or by-product. However, it is conceptually not possible to produce a co-product (CTO) from a residue (CSS). CTO could, however, in theory be classified as a product from a CTO plant or an intermediate product which needs further distilling/refining before turning it into an end product. CTO is produced (acidulated) from CSS, a residue which pulp mills have to dispose, it can either be burned as process fuel or processed into CTO in a CTO plant. No other disposal options exist. Most mills prefer to transform CSS into CTO due to technical issues associated with burning CSS and in order to add some additional value. Most CTO plants are located on-site at pulp mills and owned by the mill, but in the US some external plants exist, mostly on-site at CTO distillers. To Ecofys' understanding no or almost no *stand-alone* CTO plants exist, which indicates that the business case of CTO as a separate end product is not good enough to justify third party investments in stand-alone CTO plants. We conclude, as we did in 2013, that CTO should be regarded as a process residue.

CTO use for biofuels did not distort CTO markets, therefore the material has a low ILUC risk

CTO is available in relatively small volumes globally. Total potential CTO supply based on available CSS is around 2.6 million tonnes. The main regions in which the material becomes available are the large pinewood regions: North-America, Scandinavia and Russia. Part of the 2.6mln tonnes potential is currently not available since, as described above, some CSS is burned in pulp mills. But if the market demands, most of the 2.6mln tonnes could become available. Current actual CTO supply and demand is about 1.75mln tonnes. Of this, about 1.4 mln tonnes is used by distillers and a smaller share of about 230,000 tonnes is used to produce biofuel. Supply and demand balance out at the market price and prices therefore are a good indicator of the tightness of the market, as are developments in global CTO storage. We observe a steep drop in CTO prices since 2015, resulting from (1) a drop in heavy fuel oil and natural gas prices, as alternative pulp mill process fuels, and (2) sluggish demand for distilled CTO products and for non-distilled CTO as oil drilling fluid. We also see that about 75,000 tonnes of CTO is kept in storage tanks in the US and Scandinavia. These indicators together show that currently sufficient supply is available for all users. The CTO market, however small, is not overly tight and a potential surplus of about 850,000 tonnes of CTO is available that could be tapped into. Of course it is possible that demand for distilled products increases again. But even if all distillers globally would run on full capacity there would be sufficient potential supply to satisfy all demand.

Based on the above we conclude that CTO use for biofuels did not cause displacement effects elsewhere, and hence CTO, a non-land using process residue, is a low ILUC risk material.

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ECOFYS Netherlands B.V. | Kanaalweg 15G | 3526 KL Utrecht| **T** +31 (0)30 662-3300 | **F** +31 (0)30 662-3301 | **E** d.peters@ecofys.com | **I** www.ecofys.com
Chamber of Commerce 30161191

1 Introduction

1.1 Wastes and residues as sustainable biofuel feedstocks

Increasing quantities of biofuels are used in road transport in the European Union. The EU has set a target of 10% renewable energy in transport for 2020 in the EU Renewable Energy Directive (RED)[1] which will be mainly met by using biofuels and currently policy makers discuss the REDII that provides the framework for EU biofuels policy up to 2030. Advanced biofuels have been stimulated in the current RED by the 'double counting provision' which allows biofuels produced from wastes, residues and cellulose materials to count twice towards national targets. This provision is now being replaced by a binding mandate for advanced biofuels in the REDII, listed in Annex IX of the directive. The 2015 'ILUC directive' already introduced a non-binding mandate for these biofuels. Crude tall oil is included in Annex IX, Part A of the existing 'ILUC directive' and the European Commission proposes to continue to grant CTO the status of advanced biofuel feedstock in its proposal for the revision of the RED for the period 2020-2030.

1.2 Crude Tall Oil as feedstock for renewable diesel

Crude Tall Oil (CTO) is a material which is generated in the wood pulp production process. The word 'tall' is means 'pine' in Swedish, which indicates that CTO is mainly generated in the pulping of softwood (pine) trees. A relatively small share of CTO is also generated when pulping hardwood trees (broadleaved). Often, a mix of softwood and hardwood is used. Tall oil is obtained from black liquor soap that is being acidulated to produce CTO. UPM, a Finnish forestry and biofuel company, produces renewable diesel from CTO in its Lappeenranta biorefinery since early 2015. The plant has a capacity of 100,000 tonnes renewable diesel.

1.3 Assessing ILUC risks and CTO classification

This study is an update of an earlier study published in 2013 that aimed to assess whether CTO is a residue and has a low risk to cause negative indirect impacts. The latter would be the case if a surplus of the material exists that can be used to produce biofuels without displacing supply for existing other CTO uses. The three main questions in the assessment are:

1. Can CTO be defined as a residue based on biofuel legislation
2. Does the feedstock create an additional demand for land (is it a low ILUC risk feed stock?)
3. Does the use of the feedstock for biofuel production cause significant distortive effects on markets?

[1] 2009/28/EC

The second and third question are closely interlinked. CTO in itself is a non-land using feedstock. A potential ILUC risk can therefore only follow from a situation in which an increase in CTO demand would displace existing uses of the material by non-bioenergy sectors (CTO distilling sector), that could in turn increase the use of vegetable oils such as soybean oil as feedstock. If the answer to question 3 is negative, than question 2 is answered simultaneously.

In the previous report we concluded that CTO can be considered as a residue. We also concluded that, even though the global market is relatively tight, a surplus of around 220,000 tonnes existed with additional opportunities to increase supply further.

2 Introduction to CTO

2.1 What is CTO and how it is produced

CTO is generated in the Kraft chemical pulping of trees for paper and other products. Another method of pulping is mechanical pulping where trees are used as a whole and cellulose is not chemically separated (from lignin and extractives).[2,3] The quantity of CTO generated in chemical pulping varies for a number of reasons. The most important parameter is the tree species used for pulping. Most CTO comes from extractives in softwood (pine trees) and only a relatively small share of CTO from extractives in hardwood (broadleaved trees). Hardwoods yields low amounts of CTO, e.g. from birch trees. The CTO extraction from hardwood can be enhanced by circulating CTO to hardwood cooking.[4] Often, a mix of softwood and hardwood is used in pulping, which yields between 1.25-4% of CTO[5].

In a Kraft mill, wood chips are treated with a cooking liquor (or white liquor) containing sodium hydroxide and sodium sulphide to dissolve the lignin (delignification) of wood in order to produce pulp. Extractives in wood (resin acid, fatty acid, neutral and oxidized substances) react with the cooking liquor. After the cooking stage, residual used cooking liquor (now called weak black liquor) is separated from pulp during a washing step. This weak black liquor contains the valuable pulp cooking chemicals[6] which are extracted from the liquor in the pulp mill recovery boiler before being re-used in the pulping process. [7] On top this weak black liquor a floating layer of soap containing solid materials is formed. This layer of soap has strong foaming properties and needs to be removed from the weak black liquor in order to allow the chemicals to be extracted in the recovery boiler. First, weak black liquor is evaporated to achieve a dry solids content of 30% for optimal removal of the soap layer and to allow combustion of the black liquor in the chemicals recovery boiler[8]. This evaporation results in strong black liquor, which is fed to the pulp mill recovery boiler. In the evaporation step the layer is soap is removed and now called Crude sulphate soap (CSS). This CSS is the material from which CTO is produced.

CSS quality varies because of differences in chemical composition due to e.g. batch processing. Therefore, before producing CTO from CSS, the residue is cleaned and homogenised to uniform the material and to ease CTO processing control[9]. Homogenised CSS is subsequently acidulated to CTO, commonly using sulphuric acid. The remaining 'mother liquor' contains valuable sodium and is often fed back into the Kraft process. The extraction of CTO from CSS takes place in a CTO facility, which is usually a production line integrated with the pulp mill[10]. Additionally a number of stand-alone CTO plants exist in north-America.[11] The Kraft pulping process and CTO extraction is pictured in Annex 1.

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[2] Knowpulp (http://www.knowpulp.com/english/)
[3] According to information obtained from UPM
[4] Interview with Dr. Panu Tikka of SciTech Service Oy Ltd.
[5] According to data obtained from UPM
[6] Sodium hydroxide and sodium sulfide, together called 'white liquor'.
[7] Knowpulp (http://www.knowpulp.com/english/)
[8] Interview with Dr. Panu Tikka of SciTech Service Oy Ltd.
[9] Knowpulp (http://www.knowpulp.com/english/)
[10] Interviews with Dr. Panu Tikka of SciTech Service Oy Ltd. and Prof. Herbert Sixta of the Aalto University
[11] Interview with Dr. Panu Tikka of SciTech Service Oy Ltd.

2.2 Main CTO uses

CTO has four main categories of uses; it can be used (1) as process fuel in the pulp mill lime kiln, (2) distilled into a variety of products, (3) used as a component of petroleum extraction drilling fluid or for phosphate mining and (4) it can be used to produce renewable diesel. In addition, some minor other uses exist. Table 1 gives an overview of the current CTO processing, products and end uses.

Table 1 CTO processing, derived products and their uses[12]

Processing	Products	Uses
Distilling	Tall Oil Fatty Acid (TOFA)	Fuel additive
		Alkyd resins
		Dimer acids
	Tall Oil Rosin (TOR)	Adhesives
		Paper size
		Printing ink
		Rubber emulsifier
	Distilled Tall Oil (DTO)	Metal working fluid
	Tall Oil Pitch (TOP)	Fuel oil, process fuel CTO distiller and other users
		Food adhesive
		Printing ink
	Tall Oil Heads (TOH)	Fuel oil, process fuel CTO distiller
Direct energy use	CTO	Process fuel for pulp mill lime kiln
Refining	Crude Tall Diesel (CTD) / Renewable diesel	Biofuel
Modifying/Mixing	Suspension stabiliser	Drilling mud for petroleum extraction
	Additive in floatation processing plant	Phosphate mining and other mineral flotation applications
Direct use	CTO	Other small uses

The five fractions to which CTO is broken down in a vacuum distillery as included in the table above have a typical breakdown as presented in the figure below:

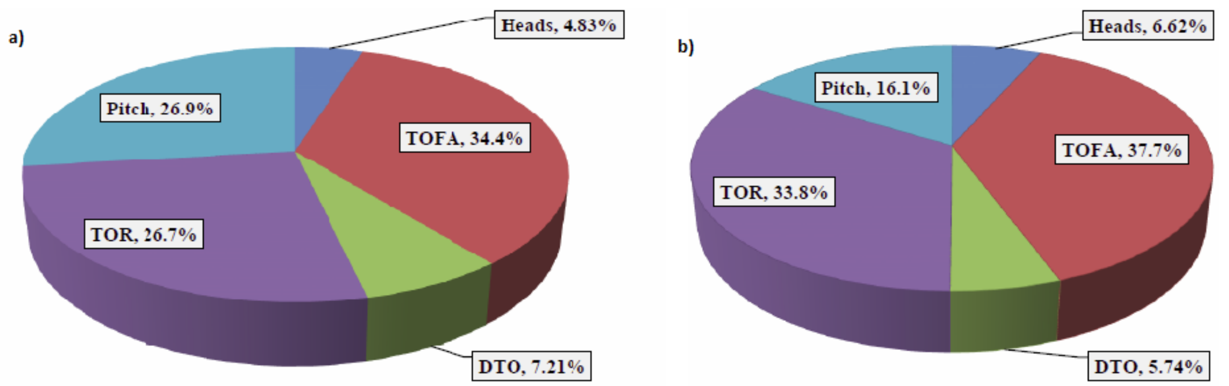

Figure 1. Average CTO Distillation Product Output in 2010/2011 in a)Europe b)USA (Percent by Mass of Total Product Output) (Franklin Associates, 2013)

[12] Data obtained from UPM and through an interview with Dr. Panu Tikka of SciTech Service Oy Ltd and

SunPine and UPM are currently the only users of CTO to produce biofuel. UPM uses CTO to produce renewable drop-in fuel. Its production process requires a final refinery process step including hydrogenation treatment which converts the CTO to biodiesel.[13]

CTO can also be used directly as a process fuel for the Kraft mill lime kiln. The chemicals recovery process in a Kraft mill produces calcium carbonate which forms a lime mud. This mud has to be separated from the recovered chemicals mixture (white liquor) by means of a clarification process. The white liquor is then ready for re-use in pulp cooking, while the separated lime mud is washed with water and combusted in a lime kiln using heavy fuel oil, gas or CTO. During combustion, the calcium carbonate is reconverted into lime, which can be used again in the chemicals recovery process.[14] Note that low distillable quality CTO from hardwood pulp mills is mostly used for these direct energy purposes.[15]

In our previous report we stated that CTO is increasingly used in the oil, gas and chemicals industries. CTO can be used as either a suspension stabilizer in drilling mud (to keep the fine particles in the mixture) or as an additive in floatation processing plant for use in phosphate mining and other mineral flotation applications. However, since the drop in oil prices in 2014 oil production has dropped and quantities of CTO used in oil drilling mud dropped significantly.

2.3 Types and qualities of CTO

No formal CTO quality categories or grades exist. Nevertheless, different qualities of CTO do exist, mainly depending on rosin acid content and acid number (AN) value, defined as milligrams of potassium hydroxide per gram (mgKOH/g) CTO. The understanding of quality depends on the end use.

Different CTO qualities, from a CTO distiller's point of view[16], are presented in table 4, which informally distinguishes between low, medium and high quality CTO. Good quality CTO is generally regarded to be CTO with an AN value over 135 mgKOH/g, a rosin acid content higher than 30% and low water and unsaponifiables content. Low quality CTO is CTO with an AN value below 135 mgKOH/g and a rosin acid content below 23%. Medium quality CTO has a rosin acid content between 23% and 30%, with an AN value below 135 mgKOH/g.

CTO with a high AN value has a high proportion of rosin acids[17]. In general, CTO distillers prefer to use a blend of CTO with a high average acid number value and a relatively high percentage of rosin acids. CTO from the USA is generally derived from good quality softwood (pine) with a high rosin acid content and therefore has a higher acid number value (160 mgKOH/g and rosin content above 35%) compared

[13] A major by-product is the so-called bio oil, a high quality tall oil pitch which can be processed further to recover valuable chemicals including rosin and phytosterols (Sunpine)
[14] Knowpulp (http://www.knowpulp.com/english/)
[15] Interview with Dr. Panu Tikka of SciTech Service Oy Ltd.
[16] Distillers use CTO as a feedstock to produce a variety of products, see chapter 5.
[17] Tall oil. A book on the processing and use of tall oil; for chemists, engineers, managers and producers (New York 1981).

to CTO from the EU (medium quality CTO with AN values of around 135 mgKOH/g and 28% rosin content). Russian CTO generally has a lower quality, with an AN value of 115 and 14% rosin content.[18]

CTO also contains fatty acids, which is an important element for non-distilled CTO-diesel. The relative proportions of rosin acids and fatty acids are related. In general the higher the rosin contents, the lower the unsaponifiables content and also to some extent the fatty acid content[19].

Table 4 CTO quality from a distiller's perspective[20]

Element	Low distillable quality	Medium distillable quality	High distillable quality
AN (mgKOH/g)	<135	<135	>135
Rosin acid (%)	<23	23-30	>30
Fatty acid (%)	40-65	40-65	35-40
Water (%)	<1.5	<1.5	<1
Unsaponifiables (%)	12-25	12-25	<12

Main factors that determine quality

The main parameters which influence wood element composition and therefore CTO yield and quality are; wood type, wood species, wood age[21], time of harvest, wood chip storage (time, temperature, moisture content) and some other indicators. High yields and high qualities of CTO are associated with the use of 100% softwood (pine) as a feedstock. Since the 1970s there has been an increase in the use of hardwood (mainly birch) in Scandinavia, which has lowered the yield and quality of CTO available in Europe[22]. However, due to the use of better feedstock and better wood chip storage facilities the net pulp (approx. 15%) and CTO (approx. 30%) yields have increased during 2010-2013.[23]

The majority of North American CTO production takes place in South-Eastern US, a region rich with southern pine trees that result in very high quality CTO. Scandinavian and Russian pulp mills, on the other hand, use Pinus Silvestris and Larix Sibirica pine trees that produce lower quality CTO. Canadian CTO is not traded at all to Scandinavia due to its low quality.

Blending various qualities

CTO distillers favour high quality CTO, but occasionally use blends with cheaper low quality CTO mixed in with more expensive high quality CTO (>45% rosin acid content)[24]. If the rosin content is lower than 28%, European distillers blend in US derived CTO in order to reach the desired rosin levels. Distillers will aim to source the cheapest possible CTO blend which still allows them to produce high quality products.

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[18] Interview (2017) with Mr. Keijo Ukkonen, Nopek Oy, a CTO trading firm
[19] Interview with Dr. Panu Tikka of SciTech Service Oy Ltd.
[20] Based on interviews with Prof. Esa Vakkilainen of the Lappeenranta University of technology, Mr. Keijo Ukkonen, Nopek Oy, a CTO trading firm and Dr. Panu Tikka of SciTech Service Oy Ltd.
[21] Interview with Dr. Panu Tikka of SciTech Service Oy Ltd. Due to a genetically determined process, old hardened softwood has a relatively high resin content, which means the CTO from old pine trees is of higher quality than that from young trees.
[22] Papermaking Science and Technology, Book 6B Chemical pulping. Editors: Gullichsen J., Fogelholm C-J.
[23] Interview with Mr. Keijo Ukkonen, Nopek Oy, a CTO trading firm
[24] Interview with Mr. Keijo Ukkonen, Nopek Oy, a CTO trading firm

While distillers favour high quality CTO, so called low quality CTO is in fact an excellent quality material to produce renewable diesel from. It is difficult to accurately define the quality CTO, although quality differences do matter. This becomes clear from the differences in the prices of CTO when traded. As can be seen in section 2.2, high quality CTO is traded at higher prices compared to low quality CTO.

It is also worth noting that some available CTO is of such 'poor' quality that it is non-distillable, the so-called 'fuel quality CTO'. Fuel quality CTO contains a relatively high level of fatty acids (up to 65%) and has a relatively low AN value (<135 mgKOH/g) and low rosin acid content (<23%)[25].

[25] Interview Dr. Panu Tikka of SciTech Service Oy Ltd.

3 The CTO market

3.1 General market characteristics

This section describes the general CTO market characteristics such as supply and demand balances, trading practices, current prices and price developments and general market trends.

The CTO market is relatively small both in terms of volumes and actors and therefore seemingly quite transparent and easy to assess. Yet, due to its limited relevance, there was never an incentive to collect data, compile statistics or develop price benchmarks on CTO. This makes it difficult to obtain full clarity on supply, demand and prices. However, even though uncertainties prevent full clarity on market specifics, the general picture is quite clear. Total global supply is dictated by the size of the global chemical softwood pulping sector, for which reliable statistics exist. Total global demand mostly comes from the chemical sector and market floor prices are determined by heavy fuel oil prices (in Europe) or natural gas prices (in the US), topped with the market value for distilled products.

Based on total global figures on chemical pulping of softwood and CSS-generating hardwood types such as birch, the total CTO production potential can be estimated to roughly 2.6 million tonnes[26]. This number can be slightly different in reality due to variations in CTO yield, and could increase following a future increase in softwood pulp mill capacity. But for today, consensus exists that global CTO potential is about 2.6 million tonnes. In reality, even though it seems to be that enough acidulation capacity exists worldwide[27], not all available CSS is acidulated into CTO. Not all pulp mills have on-site CTO production capacity. Many mills, especially older mills in the US, use part of their CSS as process fuel and transporting CSS over long distances to external acidulation capacity is not always economical.

As in any other market, supply and demand balance usually form an equilibrium at a certain price, with higher stocks indicating a market with abundant supply. Looking at prices, CTO has a floor price the equivalent of the value of heavy fuel oil plus EU ETS price per avoided tonne of carbon (in the EU) or the value of natural gas (US), as CTO can be used to substitute these fossil fuels as pulp mill lime kiln process fuel. On top of this floor price additional value is added through the demand for distilled CTO products (such as tall oil rosin). The latter is impacted by fossil fuel prices since it competes with rosins from hydrocarbon origin.

CTO has become a globally traded commodity as indicated by European trade statistics[28]. CTO is traded either via long term partnership agreements between pulp mills and distillers or sold at contracts with a typical duration of 1 to 3 years. The majority of the material is traded at such short term contracts.

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[26] Interview with UPM CTO market expert as well as in line with the Pöyry "Global Tall Oil Availability Final Report, 2017"

[27] Pulp mills externally reported acidulation capacity plus off-site CTO plants add up to 1.9 to 2.1Mt of total CTO capacity, however acidulation capacity is relatively inexpensive and often mills installed slightly oversized capacities.

[28] Eurostat http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/. EU trade data since 1988 by CN number (CTO code is 38030010)

3.2 Global production of CTO

This section first describes the global total potential of CTO production, followed by the current production level. The total potential is the production which could be achieved if all chemical pulp mills would have an on-site CTO facility or if sufficient off-site CTO plants exist to process the available CSS. The total potential is influenced by the share of softwood (pine) input in the pulp mill because pine pulping leads to considerably higher CTO yields than hardwood input. Pöyry, a consulting firm specialising in forestry and pulp and paper, estimates[29] that around 320 **chemical pulp mills worldwide have the potential to produce 2.6 million tonnes[30] of CTO per year**, a potential that has remained constant over the past 3 years. This potential has been confirmed by other industry experts[31]. It can be expected that this potential can increase in coming years as global softwood pulping capacity is expected to increase. Another 100,000 t of CTO raw material is expected to become available in the next three years in the US, plus 80,000 t from two new softwood pulp mills in Scandinavia.

Although not even half of all global chemical pulp mills with CTO potential have a CTO facility, the majority of mills in Europe do. From the around 63 chemical pulp mills with CTO potential located in Europe (excluding Russia), around 51 have an on-site CTO plant.[32] These mills could produce some 700,000 tonnes of CTO. This means that approximately 28% of the global CTO production potential is located in Europe. In addition to acidulation capacity at pulp mills, off-site CTO plants exist in the US with a combined capacity of around 210,000 tonnes[33], up from 150,000 tonnes in 2013. These plants are often located at the site of a CTO distiller.

While the CTO potential assumes that all CSS generated in chemical pulp mills can be acidulated into CTO, Pöyry estimates that some 148 of the 321 mills worldwide have an on-site CTO production line[34]. Pöyry estimates that the current CTO **production potential** of these 148 facilities is around **1.85 million tonnes**., based on CSS being generated in those mills. However, often mills have excess acidulation capacity available that could be used to acidulate CSS generated in other mills. This means that in reality the **total global acidulation capacity is (much) higher than 1.85 million tonnes**. It is difficult to estimate the precise quantity of CTO being acidulated from CSS. To what extent do mills burn part of their CSS as process fuel? To what extent do mills without own acidulation capacity ship their CSS to other mills that do have acidulation capacity? Experts agree that virtually all CSS from Scandinavian mills is acidulated to CTO and also Russian CSS is mainly acidulated. Also, it is understood

[29] The information provided by Pöyry Management Consulting Oy, ("Pöyry") included in this report has been prepared by Pöyry for the use of UPM only and therefore there is no certainty that the information addresses or reflects the specific requirements, interests or circumstances of any other party. Further the estimates and conclusions given in the information are based partly on information not within Pöyry´s control. Pöyry does not make any representation or warranty as to the accuracy, correctness or completeness of these estimates or of any analysis thereof contained in the report by Ecofys or any other recommendation, representation or warranty whatsoever concerning this report. Pöyry has no duty to update or supplement any information provided. Any reliance placed on the information is a matter of each investor's or other third party's judgment exclusively and solely at their own risk. Pöyry is not responsible for any actions (or lack thereof) taken by any investors or other third parties as a result of relying on or in any way using the information and in no event shall Pöyry be liable for any damages of whatsoever nature or type resulting from reliance on or use of the information whether such liability is asserted to arise in contract, negligence, strict liability or other theory of law.

[30] Also confirmed by UPM CTO market expert

[31] Interview with UPM CTO market expert

[32] Information obtained from Pöyry.

[33] Interview with Keijo Ukkonen, CTO trader

[34] This number represents all mills including the ones that utilize hardwood.

that in the US, a significant share of CSS is not acidulated, but precise numbers are not available. This means that estimates on current total global production vary.

Pöyry estimates the **current actual production to be 1.6 million tonnes, whereas others estimate production to lie around 1.8 to 2 million tonnes**[35] The latter figure is in line with our estimate in our 2013 report on CTO. It is clear that acidulation varies depending on market demand for CTO. If demand increases, supply will follow. Therefore it makes sense to analyse recent developments in CTO demand.

3.3 CTO demand for distilling and other uses

As no statistics exist on the quantities of CTO used for various purposes this section gives estimated figures obtained from various sources. It is clear that CTO distillation represents by far the largest end use, currently processing around 1.4 million tonnes annually, down from 1.5 million tonnes in 2013 of CTO annually.[36] This decrease results from lower oil prices which lowered the price of hydrocarbon rosins which put pressure on the demand for CTO-derived rosin. CTO for the production of TOFA decreased due to cheaper mixed fatty acids becoming available as substitutes. In addition, the use of oil based muds for oil drilling has been decreasing to about 80,000 tonnes due to the drop of heavy fuel oil prices and the improvements in fracking techniques[37]. This is a drastic reduction compared to 2013 when the CTO use for oil drilling muds was around 150,000 tonnes. The CTO refining industry that produces biofuel uses around 230,000 tonnes of CTO, up from 60,000 tonnes in 2013[38]. Smaller uses of CTO, direct energy use and mineral flotations add up to approximately 40,000 tonnes[39]. All these uses combined lead to a **total current estimated CTO demand of 1.75 million tonnes**. Figure 2 illustrates the relative shares of the various CTO uses.

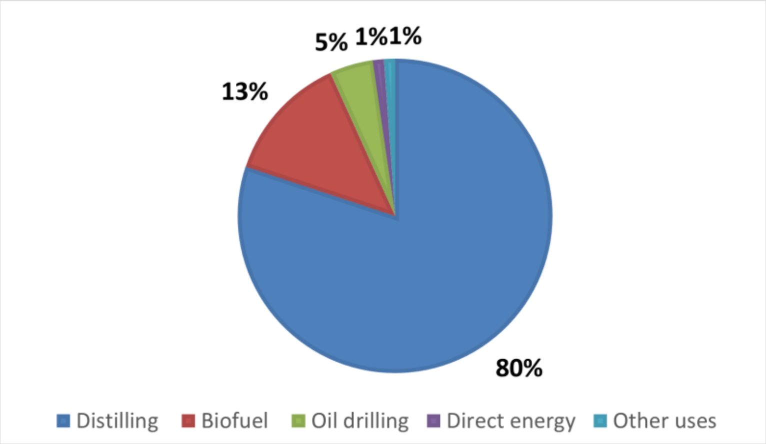

Figure 2 Relative share of various global CTO uses[40]

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[35] Mr. Ukkonen and UPM CTO expert
[36] Data received from UPM CTO market expert
[37] Interview with Keijo Ukkonen, CTO trader
[38] Data received from UPM CTO market expert
[39] Data received from UPM CTO market expert
[40] Data received from UPM CTO market expert

Future outlook

There are currently three projects for new distilling capacity (around 260,000 t)[41]. However, investment decisions have not been made as it is not clear if the rosin market is large enough to absorb all the potential additional volumes. There is, however, enough raw material at disposal for all three plants, especially considering the new pulp mills that are expected to come online in the next three years.

3.4 Comparing supply and demand

As described in the previous section, CTO has four main categories of uses. It can be used as process fuel in the pulp mill lime kiln, distilled into a variety of products, used as a component of petroleum extraction drilling fluid or for phosphate mining. It can also be used to produce biofuel and finally, some other small uses exist. Using CTO to burn as process fuel in the pulp mill lime kiln is a form of bioenergy. Steering this CTO towards biofuel production does not increase the risk of Indirect Land Use Change. The lime kiln would in this case increase its use of natural gas as process fuel or could resort to other forestry residues as bioenergy process fuel. Current CTO used in biorefineries to produce biofuel is already used for biofuel and this use does thus not displace other uses and cause ILUC.

CTO currently used in distilleries and as a component in drilling mud cannot be diverted towards biofuel use without potentially risking Indirect Land Use Change and have to be deducted from the total CTO production potential. Distilled CTO into various products (TOR, TOFA, TOP, DTO) is used for many purposes as described in the previous chapter. Steering CTO away from distilling means that alternatives have to be used for all these purposes; possibly leading to ILUC if agricultural crops are used as alternative feedstocks. If less CTO is available for drilling fluids, the fatty acids have to be sourced elsewhere e.g. from vegetable oil, with a potential risk of causing land use change.

The estimated current total CTO production is estimated to be 1,75 million tonnes per year worldwide. This matches the total demand of various CTO uses. If this number is compared to the global potential CTO production of 2.6Mtonne, a surplus potential of 850,000 tonnes exist. This large excess potential partly results from the fact that distillers currently don’t run on full capacity for reasons explained above. If all distillers would run on full capacity, this would add around 600,000 tonnes of demand. Still, in such scenario there would be sufficient potential supply (250,000 tonnes) to satisfy demand from all market players. The notion that sufficient CTO exists is confirmed by the fact that significant quantities of CTO are currently kept in storage tanks: about 50,000t in US and 25,000t in Europe and the fact that market prices are low, as is described in the next section. Table 6 below shows the supply and demand comparison.

[41] Interview with Keijo Ukkonen, CTO trader: 100,000 t capacity in US (Georgia-Pacific), 200,000 t extra capacity in the Nordics (classified), 60,000 t in India (Privy Organics Ltd.)

Table 6 CTO low ILUC potential estimate

Deducting CTO uses with potential ILUC risk from CTO production level results in CTO low ILUC potential	CTO quantity in tonnes
CTO potential supply	2,600,000
Estimated current CTO production	1,750,000
Distilleries	1,400,000
Petroleum drilling fluid	80,000
Other uses (Phosphate mining, direct energy)	40,000
Biofuel production	230,000
Excess potential that could be made available	**850,000**
Additional demand if distillers run at full capacity	**600,000**
Excess potential if distillers run at full capacity	**250,000**

3.5 CTO prices

As explained in previous sections, three main regional markets exist for CTO: the US, Scandinavia and Russia. CTO qualities and prices differ between these regions.

CTO has a floor price the equivalent of the value of heavy fuel oil plus delivery costs as well as the EU ETS price per avoided tonne of carbon (in the EU) or the value of natural gas (US), as CTO can be used to substitute these fossil fuels as pulp mill lime kiln process fuel. On top of this floor price additional value is added through the demand for distilled CTO products (such as tall oil rosin). The latter is impacted by fossil fuel prices since it competes with rosins from hydrocarbon origin.

In Scandinavia the following price formula is used to understand the CTO floor price:

CTO price / tonne = (0,9 x HFO price (<1%S)) + 30 €/tonne + (2,9 x CO_2 price)[42]

Prices in 2013

As said, there is a major difference in prices between the different CTO qualities. Back in 2013 high quality CTO had a floor price of around 550 €/tonne Ex-works, while Low quality CTO costed around 400 €/tonne Ex-works. Medium quality CTO fluctuates somewhere in the middle.[43] In Europe fuel quality CTO could be bought from pulp mills at 380 €/tonne Ex-works. In general low quality CTO is 20-30% lower in price than high quality CTO[44].

[42] Interview Dr. Panu Tikka of SciTech Service Oy Lt.
[43] Interviews with Mr. Keijo Ukkonen, Nopek Oy, a CTO trading firm and Dr. Panu Tikka of SciTech Service Oy Ltd.
[44] Interview Dr. Panu Tikka of SciTech Service Oy Ltd.

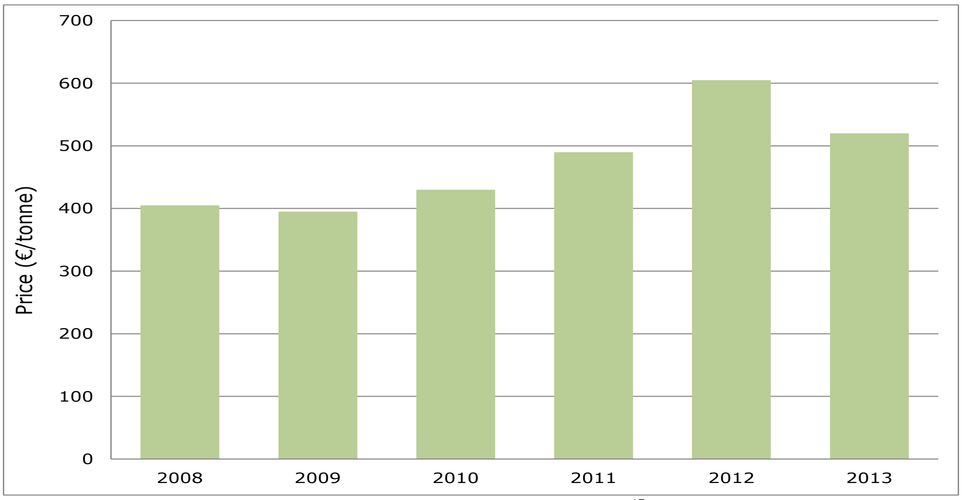

Figure 2 worldwide floor price developments for good quality CTO[45]

While the price of CTO increased in 2008-2013, the price of its precursor CSS has remained very low. In the USA the price for CSS was roughly 2 to 4 cents per pound Ex-Works in 2013, in the EU the CSS price roughly varied between 50 and 100 €/tonne Ex-works.

Current prices

In 2014 global crude oil prices collapsed and so did prices for derived products such as heavy fuel oil. This development had a strong impact on CTO prices which steeply decreased from €550/tonne €/tonne ex-works for good quality CTO in 2013 to about 320 €/t ex-works in Scandinavia in 2016[46] and 243 €/t ex-works in North America in 2016. In 2015 the price of US-derived CTO transported to Scandinavia costed around €550 per tonne, a year later the price dropped to €460 and in early 2017 the price stabilised at around €350 per tonne.[47]

CTO prices are expected to strengthen towards the end of the year, but there should not be major increase as there is a lot of inventory available, large amounts of CTO are being produced at the moment and the consumption has not increased.

[45] Data obtained from the Arbo Value Ltd Oy database owned by Dr. Panu Tikka
[46] UPM CTO expert
[47] Interview with Mr. Ukkonen

4 Regional CTO markets and trade patterns

The following chapter describes the three largest CTO markets and their trade patterns. Table 5 provides an overview of the regional maximum available CTO supply, demand and uses.

Table 5. Regional CTO demand, supply and uses

Region	Supply[48]	Demand[49]	Uses
Scandinavia	440,000 t	640,000 t	Distilling, biofuel, energy uses
USA	830,000 t	690,000 t	Distilling, oil drilling, other uses
Russia	160,000 t	200,000 t	Distilling, energy uses
Share of global market	91%	88%	

4.1 Scandinavia

CTO production in Scandinavia is mainly located in Sweden and Finland. This region has plenty of softwood harvest potential. The CTO used in this region is partially supplied by local mills and partially imported. The import/export balance of CTO in this region has remained stable in the past four years with Europe remaining a net importer with almost all CTO bought from the USA[50]. Figure 3 shows that CTO import from the USA has been steadily increasing over the past years and has tripled since 2008. Currently, Sweden and Finland are the top CTO importers from Europe. Imports mainly relate to demand for CTO distilling but are also linked to demand for biofuel production. Approximately 15% of the CTO used in Scandinavian distilleries is sourced from the US[51]. CTO export value to the US remains quite small[52]. Next to US imported CTO, Russian CTO, in smaller amounts, is also imported in this region. Most of the CTO imported from Russia is supplied to mills in Finland (Figure 4). US CTO is preferred in this market as it has higher quality than Russian CTO.

Almost all pulp mills in Scandinavia own their own acidulation plants. The few mills that do not have one usually burn their black liquor soap[53]. The amount of mills that burn soap is decreasing due to the rising incentives to go to market[54]. This is the main reason why the Scandinavian region has one of the

[48] Pöyry "Global tall oil availability report, 2017": Data presented here gives the estimated actual tall oil production (excluding off-site acidulation)
[49] Data from UPM CTO market expert
[50] Eurostat http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/. EU trade data since 1988 by CN number (CTO code is 38030010)
[51] Franklin associates, 2013.
[52] 2008: €732,- worth of CTO from Sweden. 2013: €13,- and €34,- worth of CTO from Finland and Sweden respectively. 2015: €15,- worth of CTO from Finland
[53] Franklin Associats 2013
[54] Interview with Keijo Ukkonen, CTO trader; Interview with anonymous market expert

highest CTO utilization rates (around 98%)[55]. Scandinavian distilling facilities often burn some of their products (DTO, pitch, heads) for fuel and combust some of their biomass during the production process instead of using fossil fuels. Both practices increase the raw material demand (Franklin associates, 2013). This could potentially be a result of insufficient natural gas pipeline infrastructure and the higher prices of its fossil alternative, heavy fuel oil. The estimated CTO potential supply in this region (assuming all pulp mills have acidulation plants) is roughly 530,000 t, while the production potential from pulp mills with existing acidulation plants (on-site) is estimated to be around 520,000 t[56]. Finally, a quantity of about 25,000 tonnes of CTO is available in storage tanks across Scandinavia.[57]

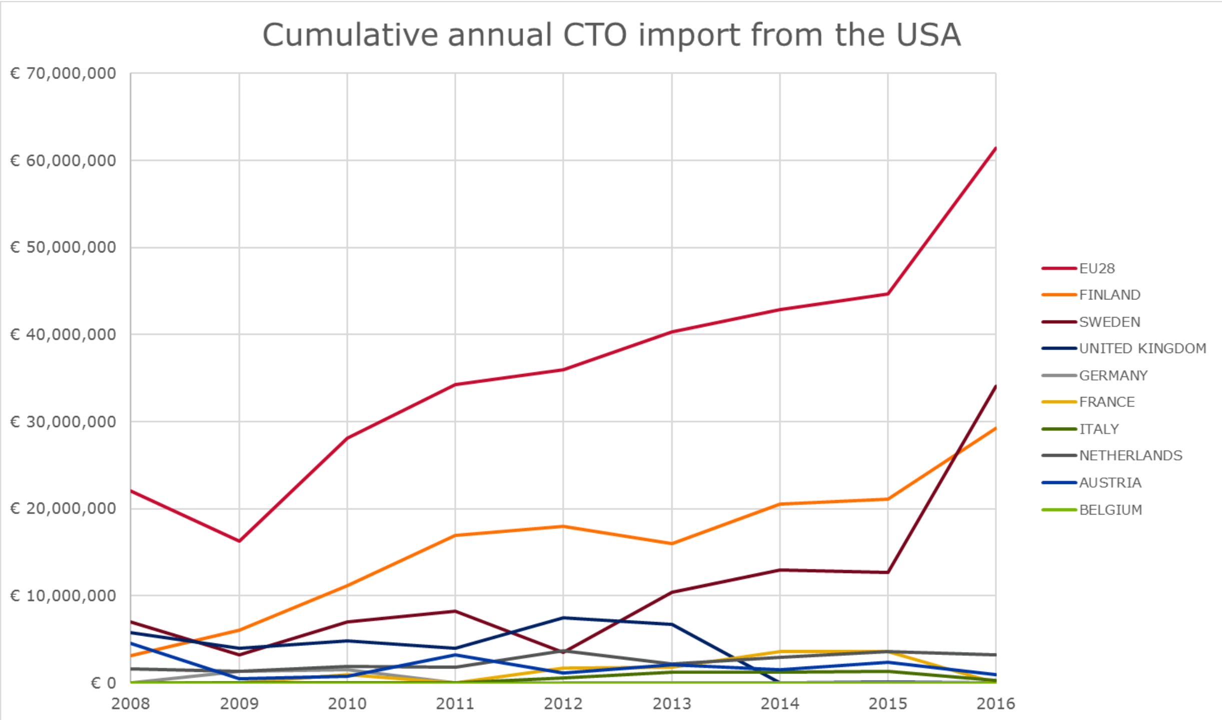

Figure 3 EU28 CTO import from the USA, including values per member state[58]

[55] Pöyry "Global tall oil availability report, 2017"
[56] Pöyry "Global tall oil availability report, 2017"
[57] Interview with Keijo Ukkonen of Nopek Oy.
[58] Eurostat http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/. EU trade data since 1988 by CN number (CTO code is 38030010)

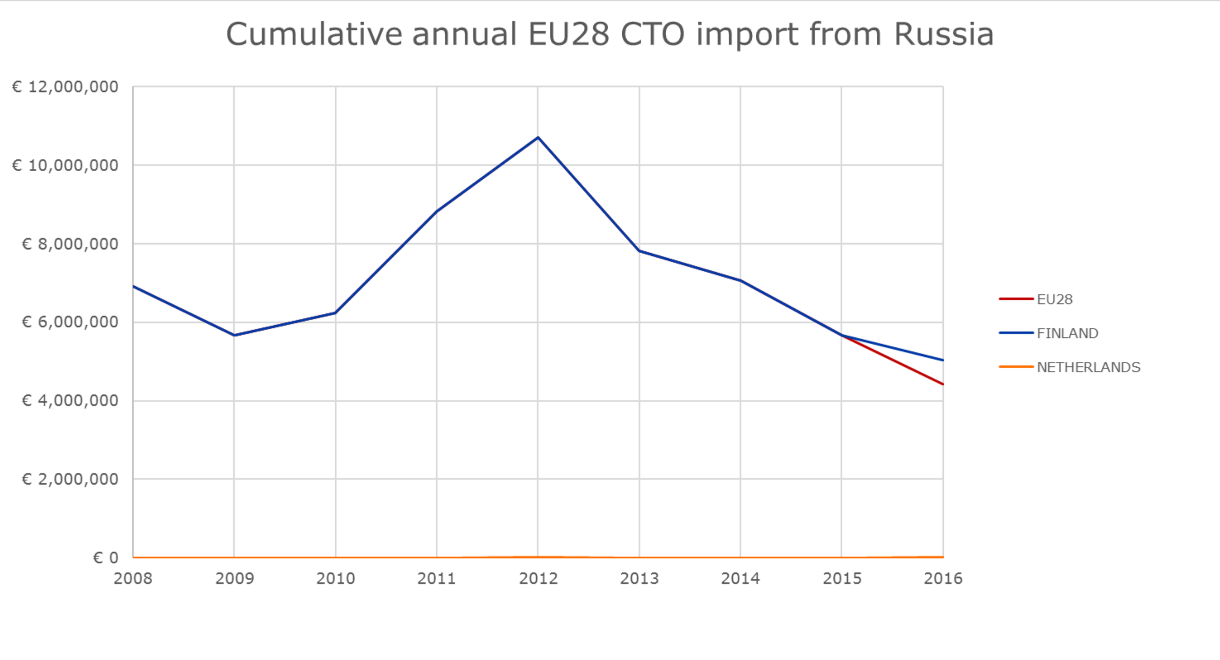

Figure 4 EU28 CTO import from Russia, including values per member state[59]

4.2 USA

The US trade market is highly related and dependent on the global market and especially supply and demand balances in Western Europe. Approximately 15% of the CTO used in West European distilleries is from the USA (Franklin Associates, 2013). This interconnection is also reflected in the drop of CTO prices in the US market that followed the drop of the European market. Currently the CTO spot prices in the USA are around 260 $/t ex-mill with additional shipping costs from USA to EU to about 150$/t[60].

The bulk of North American CTO production is based in the South Eastern part of USA, which is rich in Lobolly Pine (Pinus Taeda), the primary type of softwood used for CTO production in this region (Franklin Associates, 2013). This softwood results in high quality CTO with AN values above 160 mgKOH/g and rosin content higher than 35%. When comparing markets, the CTO produced in USA is the highest quality CTO on the market[61].

In contrast to Scandinavian practices, quite a big share of acidulation in the US happens off site (approximately 37% or around 210,000 t CTO[62]. Off-site acidulation mainly takes place in the distilleries. Another major difference between US and Scandinavian practices is the fuel source. As previously

[59] Eurostat http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/. EU trade data since 1988 by CN number (CTO code is 38030010)
[60] Interview with Keijo Ukkonen, CTO trader
[61] Interview with Keijo Ukkonen, CTO trader
[62] Interview with Keijo Ukkonen, CTO trader; Franklin associates, 2013

mentioned, European distillation facilities often use some of their products or raw biomass as substitute for heavy fuel oil, while the majority of US facilities largely depend on natural gas as process fuel[63].

The potential CTO supply in this region (assuming all pulp mills have acidulation plants) is around 1,340,000 t, while the potential CTO production from pulp mills with existing acidulation plants (on-site) is estimated to be around 920,000 t[64].In addition to this capacity, the USA holds around 50,000 t of CTO in storage tanks.

4.3 Russia

The Russian CTO market differs from the Scandinavian and the USA one, both in supply and demand balances and in production infrastructure. This market is influenced more by the local supply and demand balance rather than the global one, meaning that large parts of the distilling products are sold in the domestic market. Russia uses CTO as fuel oil, in the mining industry and in distilling[65].The majority of the industry infrastructure is old and inefficient compared to the Scandinavia and the US. Some of the mills are obsolete (old and don't run constantly) and there are no investments in infrastructure improvements. These mills partially burn CSS, meaning they do not reach the maximum CTO production potential. Pöyry data shows very high CTO utilization rates with a slight decrease in recent years (from 100% to 96%), which could indicate slight increase in CSS burning. Other experts, on the other hand, state that the amount of mills burning of CSS has been decreasing recently[66]. Many of the mills produce low quality CTO that is not fit for distilling, partially due to the mills infrastructure and partially due to the types of softwood available in this region (Pinus Silvestris and Larix Sibirica) which result in lower quality CTO. The CTO produced in Russia has an AN value of 115 and rosin content of 14%[67]. This is why Russian CTO prices market prices are a lot lower compared to other regions, with prices of around 120 €/t ex-mill[68], lower than the price of CTO from the other two markets. Russian distilling plants were built in the 1970s and 1980s and face similar inefficiencies as the pulp mills. For instance, the distilling capacity utilization rates in Russia are quite lower than the rest of the operating regions, 60% compared to 80% (USA, Sweden)-90% (Finland)[69]. In general, the Russian market is considered as a source to be further developed by experts[70]. The estimated potential CTO supply in this region (assuming all pulp mills have acidulation plants) is roughly 240,000 t, while the potential CTO production from pulp mills with existing acidulation plants (on-site) is estimated to be around 230,000 t[71].

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63 Franklin associates, 2013
64 Pöyry "Global tall oil availability report, 2017"
65 Interview with UPM CTO market expert
66 Interview with an anonymous CTO market expert
67 Interview with Keijo Ukkonen, CTO trader
68 Interview with Keijo Ukkonen, CTO trader
69 Data received from UPM CTO market expert
70 Interview with an anonymous CTO market expert
71 Pöyry "Global tall oil availability report, 2017"

5 Defining the status of CTO

CTO is a feedstock which to a large extent is modified or distilled into derived products and not a material which the holder discards or intends to discard. Therefore, CTO does not meet the definition of a waste included in the EU waste framework directive 2008/98/EC: 'any substance or object the holder discards or intends or is required to discard'. Hence, the question is whether CTO is a residue, co-product or product. The EU ILUC Directive, (EU) 2015/2013, includes a definition of processing residue: 'a substance that is not the end product(s) that a production process directly seeks to produce; it is not a primary aim of the production process and the process has not been deliberately modified to produce it.' We will examine whether CTO complies with the three elements that are mentioned in the definition.

Is CTO the end product that a production process directly seeks to produce?
CTO is generated in the process to produce pulp from softwood. The direct aim of this production process is to produce pulp, not CTO. This is underpinned by the fact that the value CTO represents only a small fraction of the total value of the pulp production process. Per tonne of pulp produced in an individual pulp mill with a mix of softwood and hardwood as feedstock, on average 1.25-4% of CTO is generated. The monetary value of CTO compared to pulp value for three UPM pulp mills lies between 2 and 4.4% and the value of CTO compared to the total output of pulp and other (co)products of these mills varies between 2.9% and 5.1%.[72] We did not update these calculations since 2013 but given that CTO prices dropped we can assume that the value of CTO compared to the total value of total pulp mill output will have decreased or at least not significantly increased.

Is CTO not the primary aim of the production process?
The primary aim of the softwood chemical pulping process is to produce pulp, not CTO. See also above.

Has the process not been deliberately modified to produce CTO?
Recital 6 of the ILUC Directive clarifies what is meant with this point: 'With a view to avoiding the incentivisation of the deliberate increase in production of processing residues at the expense of the main product, the definition of processing residue should exclude residues resulting from a production process which has been deliberately modified for that purpose.' The EU RED also states that the primary technology choice for a process should not be determining. Instead the optimisation and management of the existing process should be determining.

CTO is produced from Crude Sulphite Soap (CSS), a pulping residue, by first cleaning/homogenising the CSS and then subsequent acidulation. The chemical pulping process is not optimised or modified to produce either CSS or CTO but optimised to produce pulp in the highest possible quantities. CSS and derived CTO mainly result from the pulping of pine trees (softwood) and to a much lesser extent the pulping of broadleaved trees (hardwood). The value of CCS or CTO is so low compared to pulp, as described further below, that the choice of wood type used is unrelated to the yield of CSS and CTO.

[72] UPM data

Also, the choice between chemical pulping (which generates CTO) and mechanical pulping (which does not generate CTO) is based on the desired specifications of the pulp, not on whether it is desirable to also generate CTO.[73] Furthermore, CTO production cannot be intentionally increased since wood raw material naturally contains only few percentages of extractive components.

From the above we conclude that CTO should be classified as a residue. Could CTO also be regarded as a co-product? In literature, the material is sometimes called a co-product or by-product.[74] But it should not be conceptually possible to produce a co-product (CTO) from a residue (CSS). CTO could in theory however be classified as an *(intermediate) product*; a final product from a CTO plant or an intermediate product which needs further distilling/refining before turning it into an end product.

CTO is produced in a CTO plant. Most CTO plants are on-site at pulp mill production lines and owned by the mill but in the US some external CTO plants exist.[75] If a pulp mill does not have a CTO production line, there is excess CSS, which can be sold to these external CTO plants that are then connected to CTO distilleries. To Ecofys' understanding no or almost no *stand-alone* CTO plants exist, which indicates that the business case of CTO as a separate end product is not good enough to justify third party investments in stand-alone CTO plants. Trade in CSS is limited and prices are low. This is due to the fact that only few off-site CTO plants exist and because the energy density of CSS is low which makes economical transportation normally only possible in a limited area around the pulp mill.[76]

The question is whether CTO is a residue or an (intermediate) product. The fact that no stand-alone CTO plants exist already indicates that CTO is not a product. CSS is a residue which pulp mills have to dispose.[77] If pulp mill owners have little sensible options other than to acidulate CSS into CTO, this step could be considered as processing a residue in order to dispose it in a responsible manner and the resulting CTO could be considered a residue. The mere fact that acidulation of CSS into CTO is a processing step does not necessarily mean CTO is not a residue. Other wastes and residues also need further processing in order to use or dispose of them. Collected used cooking oil (UCO), for example, needs to be cleaned and filtered before it can be used as a biodiesel feedstock. In order to assess consider to what extent CTO production from CSS is predetermined, it is important to consider the use options for CSS.

CSS is a chemical pulp mill process residue with two possible uses. It can either be burned in the pulp mill recovery boiler to recover the bound sodium and low energy value of the lipophilic extractives[78] or be used to produce CTO. The purpose of the recovery boiler is to extracted used chemicals from black

[73] Knowpulp (http://www.knowpulp.com/english/) states that 'The final application of the pulp in question is the determining factor in choosing the right process. Consequently, the two processes do not compete with, but complement one another. This is due to the fact that, even though each process has been in use for over 100 years, neither has rendered the other obsolete; the two processes have developed over the years side by side'.
[74] Gullichsen J., Fogelholm C-J. ed., *Papermaking Science and Technology, Book 6B Chemical pulping*, (1999) p. B378.
[75] It is estimated that 150,000 tonnes of the total worldwide CTO production capacity of 1.86 million tonnes is situated off-site from pulp mills, which is 8%; information from Pöyry and interview with Dr. Dr. Panu Tikka of SciTech Service Oy Ltd.
[76] Interview with Prof. Esa Vakkilainen of the Lappeenranta University of technology
[77] Interview with Mr. Keijo Ukkonen, Nopek Oy, a CTO trading firm.
[78] Interview with Dr. Dr. Panu Tikka of SciTech Service Oy Ltd. CSS is chemically the saponified fatty and rosin acids and some neutral lipophilic extractives of softwood species. Neutral lipophilic are wood extractives and are not solvable in water. Their value is the carbon, hydrogen and sodium content.

liquor, as described in section 2.1, but CSS can also be burned in the recovery boiler. From a technical perspective all CSS generated in a pulp mill could be burned in the recovery boiler, in reality mill often prefer not to burn CSS, for three main reasons:

1. Burning CSS takes up scarce boiler capacity which is better used to burn black liquor;
2. Burning CSS increases the pulp mill NOx emissions;[79]
3. Burning CSS can pose a technical challenge for the boiler.
4. Upgrading CSS to CTO can add turn a low value residue into a higher value residue material

The first and third reasons are further explained below.

Burning CSS takes up scarce boiler capacity

Boiler capacity is often the limiting factor in the pulp mill pulping capacity. The recovery of pulp production cooking chemicals is important in order to feed them back into the pulping process and keep production going. For a pulp mill it is important that all weak black liquor is fed into the boiler and if no spare boiler capacity is left, no CSS will be burned. The quantity of CSS which can be burned is therefore limited by the capacity of the recovery boiler. The recovery boiler is the most expensive installation in the pulping process. In older boilers, adding around 10% additional capacity is possible by modifying the air system at a cost of around €10 million excluding down-time costs. Increasing the boiler capacity of newer boilers has a considerable higher cost. When building a completely new pulp mill the boiler capacity could be built with the intention of burning all CSS. This would add less than €10 million to the total investment of €800 million for a 500,000 tonnes pulp mill.[80] Adding boiler capacity in order to burn the residue CSS could thus be cost-efficient for new mills but is expensive for existing mills not designed to burn all CSS.

Burning CSS can pose a technical challenge

Burning CSS in the pulp mill recovery boiler can also pose a technical challenge for boilers. CSS has a much higher fuel heat value than black liquor and its properties, especially residual black liquor (water) content, can vary. This can present a recovery boiler burning control issue and even a disturbance hazard.[81] Also, burning CSS requires a separate way of input into the boiler, because CSS in the evaporator can cause foam forming with detrimental effects to boiler operations. This separate input can lead to fluctuating CSS input into the boiler which can have a negative impact on the boiler performance.[82]

In Finland more than half of all mills are running on full recovery boiler capacity (completely taken up by black liquor). However, even if there is capacity they are reluctant to burn CSS due to the above mentioned three recovery boiler control reasons.

<u>Burning CSS hardly takes place in the EU</u>

As described above, burning CSS in the pulp mill recovery boiler is often economically unattractive, increases NOx emissions and can pose a technical challenge for the recovery boiler. Based on these

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[79] Interview with Prof. Esa Vakkolianen of Lappeenranta University of technology.
[80] Information obtained from Pöyry.
[81] Interview with Dr. Panu Tikka of SciTech Service Oy Ltd.
[82] Interview with Prof. Esa Vakkilainen of Lappeenranta University of technology

reasons, pulp mill owners often have little sensible choice but to acidulate CSS. According to Dr. Panu Tikka of SciTech Service Oy Ltd, a consultancy specialised in biomass conversion technology, CSS is hardly burned in modern pulp mill recovery boilers.[83] According to Prof. Esa Vakkilainen of the Lappeenranta University of technology 99% of EU pulp mill recovery boilers do not burn CSS but use it to produce CTO on an on-site CTO plant.[84] This is in line with insights from Pöyry that 96-98% of CSS from European mills is acidulated into CTO.[85] Even if a pulp mill has spare boiler capacity, pulp mill owners are reluctant to burn CSS due to boiler control issues described above. This means that CTO production should be considered an almost predetermined step to dispose residue CSS in the pulping process and CTO can be classified as a residue.

Based on the above we conclude that CTO should be considered as a process residue. The fact that CTO has many *existing uses* including distilling into various further products is unrelated to the question whether or not CTO is a residue but related to the question whether this residue is used to produce further products.

[83] Ibidem.
[84] In Sweden, a debate is ongoing to prohibit the burning of CSS altogether.
[85] Pöyry 2017

6 Conclusions

The current report is an updated version of the 2013 report Ecofys prepared on the status and sustainability of CTO used as feedstock for renewable diesel production. CTO is a material that is generated in the wood pulp production process. Ecofys studied the following questions in this report:

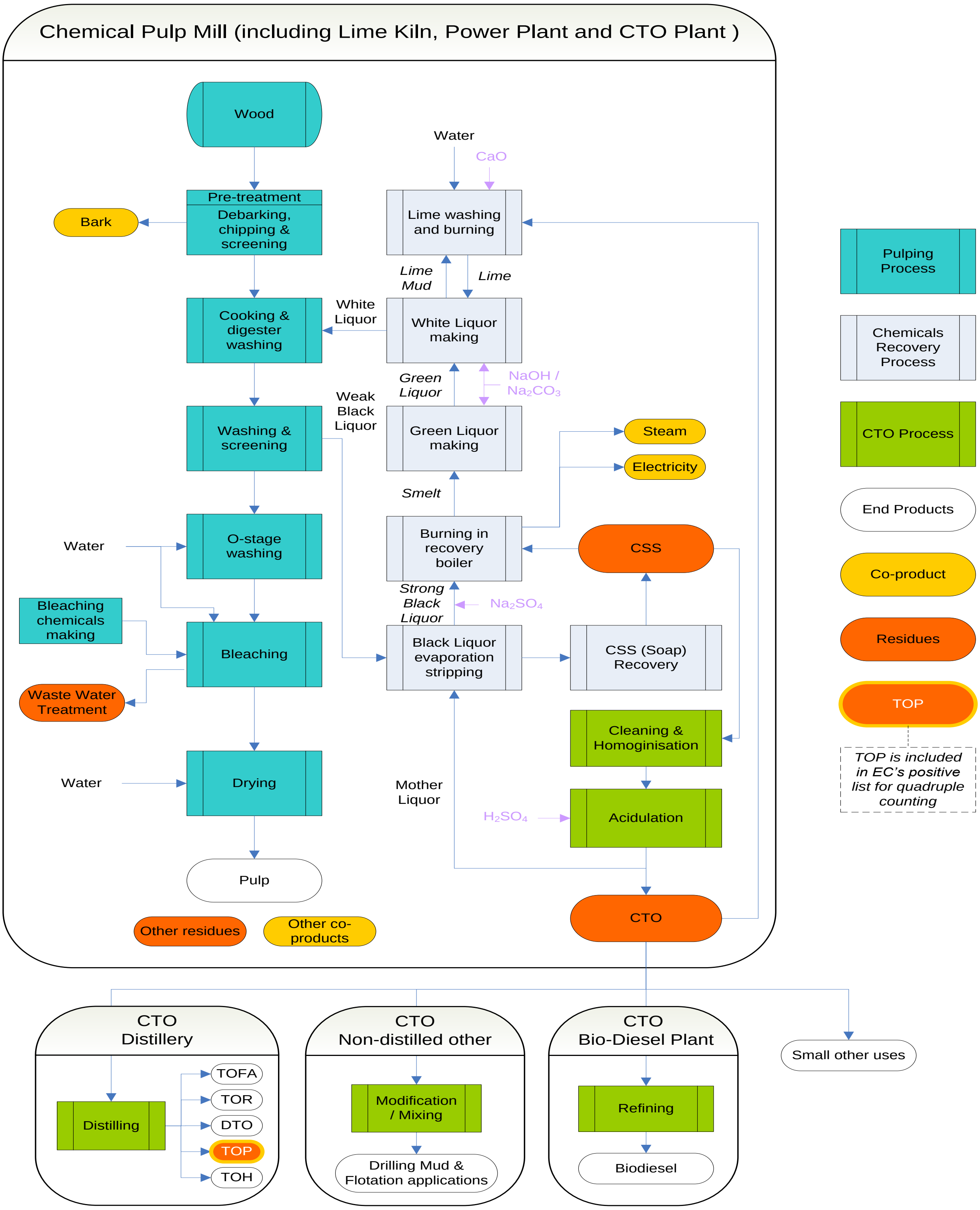
1. Can CTO be defined as a residue based on biofuel legislation
2. Does the feedstock create an additional demand for land (is it a low ILUC risk feed stock?)
3. Does the use of the feedstock for biofuel production cause distortive effects on markets?

The second and third question are closely interlinked. CTO in itself is a non-land using feedstock. An ILUC risk can only occur when an increase in demand for biofuels displaces demand for other sectors.

CTO fits the definition of process residue based on biofuel legislation
The report concludes that CTO fits into the definition of process residue. The EU ILUC Directive includes a definition of processing residue: 'a substance that is not the end product(s) that a production process directly seeks to produce; it is not a primary aim of the production process and the process has not been deliberately modified to produce it.' CTO is generated in the process to produce pulp from softwood. The pulping process directly seeks to produce pulp, not CTO. This is underpinned by the fact that the value CTO represents only a small fraction of maximum 5% of the total value of the pulp production process. The choice between chemical pulping (which generates CTO) and mechanical pulping (which does not generate CTO) is based on the desired specifications of the pulp, not on whether it is desirable to also generate CTO and CSS, the precursor of CTO is derived as process residue in relatively fixed quantities. The pulping process cannot be modified to produce more CSS and less pulp.

CTO use for biofuels did not distort CTO markets, therefore the material has a low ILUC risk
CTO is available in relatively small volumes globally. Total potential CTO supply based on available CSS is around 2.6 million tonnes. Part of the 2.6mln tonnes potential is currently not available since some CSS is burned in pulp mills. But if the market demands, most of the 2.6mln tonnes could become available. Current actual CTO supply and demand is about 1.75mln tonnes. Of this, about 1.4 mln tonnes is used by distillers and a smaller share of about 230,000 tonnes is used to produce biofuel. Supply and demand balance out at the market price and prices therefore are a good indicator of the tightness of the market, as are developments in global CTO storage. We observe a steep drop in CTO prices since 2015, resulting from (1) a drop in heavy fuel oil and natural gas prices, as alternative pulp mill process fuels, and (2) sluggish demand for distilled CTO products and for non-distilled CTO as oil drilling fluid. We also see that about 75,000 tonnes of CTO is kept in storage tanks in the US and Scandinavia. These indicators show that currently sufficient supply is available for all users. The CTO market is not tight and a potential surplus of about 850,000 tonnes of CTO is available that could be tapped into. Of course, it is possible that demand for distilled products increases again, yet if all distillers globally run on full capacity, sufficient potential supply is available to satisfy all demand. Based on this we conclude that CTO demand for biofuels did not cause displacement effects elsewhere, and hence CTO, a non-land using process residue, is a low ILUC risk material.

Appendix 1 – Chemical pulping process and CTO



ECOFYS Netherlands B.V.

Kanaalweg 15G
3526 KL Utrecht

T: +31 (0) 30 662-3300
F: +31 (0) 30 662-3301

E: d.peters@ecofys.com
I: www.ecofys.com