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# Summary

This report explores new opportunities and value added activities for circular and bio-based economy at local scale. It brings insight into the potential of valorising local lignocellulosic biomass in the province of Gelderland at one selected industry: paper and board. The use of fibres from locally available or cultivated biomass can make a crucial contribution to the future mix of raw materials for the paper and board industry. It allows reducing dependence on imported pulp made from virgin fibre from wood, keep the carbon stored in a product and by possibility of recycling several times it can stay longer in the cycle. This is supportive of reaching targets to combat climate change and contributes to circular economy.

The report provides information about the availability of lignocellulosic biomass in the region, the current status of the paper industry in Gelderland, new initiatives for lignocellulosic biomass growing and processing and enabling and restricting factors. The different type of players are mapped that can enable new value-chains to be formed with local lignocellulosic biomass in the paper and board industry. An overview of the policies at European, national and provincial level is provided, which show that the frameworks are there, and the challenge now is to bring the missions into practice, to realize the bio-economy, create new perspectives for regional economies in balance with the planetary boundaries.

A stepwise case study methodology is applied at the example of eggbox made from grass fibres to investigate the different aspects of the business case: technology, environment, economy, society and circularity. For cardboard the key is low prices. Yet, imported wood pulp as feedstock is relatively cheap due to economies of scale. The locally produced combined with higher sustainability is attractive for certain customers and they are willing to pay a premium. The market increasingly demands sustainable packaging. The technology for refining the grass into fibre is well established, however the process can be further improved by better valorising the side stream into biogas, which will provide more than enough to meet its own energy demand. The cardboard produced using grass fibres offers the same protection properties and can be recycled with the old paper for reuse. The use of local feedstock will support regional bioeconomy development and is also good to achieve security of supply with the volatility in price and availability of recycled paper in recent years. Grass has a short growth cycle and large amounts arise from waterways management, so valorising them for materials allow high resource use efficiency. It will also allow reducing demand on forests. In terms of circularity, the utility of grass fibres is maximised in material application rather than breaking it down with composting. With the possibility of recycling with old paper the value of the resources is preserved. The analysis shows that although there is room for improvement, the business case is attractive. There are new initiatives exploring these innovative value chains. Due to the strong paper industry of Gelderland, there is potential that the national lignocellulosic resources can be valorised here as a lignocellulose hub. This calls for strengthened communication and collaboration between many partners (feedstock suppliers, technology providers, knowledge an testing institutes/centres, paper industry, cluster organisations and municipalities) to develop local value chains and to increase the number and volume of the applications.

# 1 Introduction

The essence of a circular economy is that products and materials keep circulating while retaining the value of the resources incorporated in it, for as long as possible. The circular economy thus calls for new opportunities for creating value, jobs and partnerships. In 2019, the European Commission adopted a comprehensive report on the implementation of the Circular Economy Action Plan.[1] Boosting the use of underutilised sources and avoiding unnecessary loss of valuable resources through landfilling and incineration are seen as essential elements. Also transition to a circular economy scores high on the agenda of the Dutch government for three key reasons: 1) the increasing demand for raw materials in the Netherlands; 2) the dependence on other countries for raw materials; and 3) the climate impact of extracting and using of raw materials.[2] They accordingly launched a Government-wide programme aimed at developing a circular economy in the Netherlands by 2050. The Dutch government has selected "Biomass and food" as one of the 5 priority economic sectors to switch to a circular economy. Also the need for more circular production systems and the valorisation of secondary biomass streams is emphasized by the Top Sectors Chemistry, Energy and Agri & Food. The TKI-BBE (Topconsortium voor Kennis- en Innovatie Biobased Economy) offer companies financial support for research projects.[3]

Worldwide, lignocellulosic biomass is currently highly underutilized and often burned on field or landfilled causing environmental problems. It is aimed to avoid this by turning them into materials. Material applications allow the carbon to be stored during their use. Furthermore, they can be recycled several times and at the end of life-cycle can be burned to recover energy. This is in line with the main characteristic of the circular economy.

There is competition concerning the use of biomass for energy and material use which will only increase in the future. Renewable Energy Directive[4] of the European Commission incentivizes the use of biomass for energy use. This is, however, not in line with the economic value and the circular economy. Also, energy use of biomass doesn't allow cascading use which extends the biomass availability in a given system. With cascading use, biomass is processed into a material and this product is used at least once more in materials before energy recovery purposes. The supply of and demand for biomass for energy applications in the Netherlands are strongly influenced by national government policy as resulting from the Klimaatakkoord (Climate Agreement). The Climate Agreement states that in the coming decades, biomass will be necessary for achieving the climate challenge through deployment as an energy source. This results in a non-level playing field for material use of biomass. The longer-term ambitions in the field of circularity will also have to be realized. Biomass should not only play a greater role as an energy source, but also as a raw material, in addition to applications as a material, to improve soil fertility and to capture carbon in the soil.

The goal of this project funded by Dutch Ministry of Agriculture, Nature and Food Security is to explore new opportunities and value added activities and bring insight into the potential of valorising local lignocellulosic biomass in province of Gelderland at one selected industry: paper and board. The reason for this selection is the strong paper production industry of Gelderland; seven of the nine Dutch paper mills are located in this province. There is availability of diverse lignocellulosic biomass in the area (wood from forest or landscape management, grasses, agricultural residues, ..), and if there is demand possibility to grow more types (e.g. Miscanthus and hemp).

The province of Gelderland drew up its circular economy agenda at the start of 2017.[5] According to the national monitor of The Netherlands Enterprise Agency (RVO), Gelderland is leader in Biobased Economy. Biobased raw materials therefore form an integral part of the circular economy agenda of Gelderland. Three pillars have been selected that have the most potential for the future. Natural fibres is one of them. Gelderland supports processing various fibre rich biomass streams into high-quality natural fibres for sustainable applications in the paper and textile industry.[6] Recently the province published the Circular Atlas Gelderland[7] where possible reduction options per sector are identified and their potential impact are provided. One of the options considered is within the paper industry to

replace fibres from wood with low value resources such as grass and biomass from landscape management.

The challenge is to find new biobased economic activities that will lead to new perspectives for the Gelderland economy, bring economic growth and job creation in balance with reduced greenhouse gas emissions. There is a requirement to map the supply (available local biomass) and demand (local industries) and match them with each other. There are currently many uncertainties about the types, quantities and qualities of the local biomass. Furthermore, there is lack of knowledge about how they are used currently, how much can be available for local industry and the technologies that will be needed in between to utilize them. The paper industry currently relies on imported pulp made from virgin fibre from wood and on recycled paper. The idea is to find new biobased alternatives for these, in order to reduce dependence on imports and on virgin harvested wood. Also, there is price volatility and availability problems for recycled paper due to changing demands around the world. By having value-added applications from local biomass to use in paper industry will provide some relief to these issues.

# 2 Methodology

The stepwise case study methodology developed by Smits and Woltjer (2017)[8] was used as basis with minor modifications to include circularity assessment. This case study methodology was developed to analyse economic and societal impacts of the circular economy and to better understand the underlying mechanisms. In this project, the assessment of the impact of the new business case on the transition path towards a circular and biobased economy was included. Thereby, this methodology provides insight in the different aspects of the business case: technology, environment, economic, society and circularity. The methodology is divided into the following steps:

1. Defining the baseline
    a. Overview of existing situation, are there environmental, social, circularity issues at stake, etc.
    b. Current use of biomass and resources
2. Defining the new business case
    a. Why it fits within the idea of a circular economy
    b. Technology required for conversion and expected future developments in technology
    c. Expected economic, environmental and social effects of the business case
    d. Enabling or restricting framework as well as governance
3. Changes in the key sector
    a. What is the key sector
    b. Change in resources used
    c. Change in products produced
4. Overall evaluation the impact on circularity, and economic, environmental, societal impact
    a. Economic
    b. Environmental
    c. Social
    d. Circularity
5. Expected effects on other sectors and alternative use of the biomass than the described business case
6. Policy options to create enabling factors and solve barriers
7. Overall conclusions

The emphasis is on the province Gelderland. The focus is on local lignocellulosic biomass use in the local paper industry. However, it has to be emphasized that going from one step to another, there is a switch from national level, to regional level, and back. The reason is that relevant data is sometimes only available at a more aggregated level.

# 3 Case Study: Local supply of lignocellulosic biomass to paper industry in Gelderland

## 3.1 Defining the Baseline

### 3.1.1 Paper industry in Gelderland and current supply of biomass to the paper industry

In the Netherlands 22 paper mills (18 companies) are active using 38 paper lines. The total production capacity amounts 3.28 million tonnes per year and the actual sales is 2.98 million tonnes per year in 2018, representing 1.96 billion Euro.[9] This industry employed 3842 people in 2018.

In 2018 the feedstocks were[9]:

- 2.63 million tonnes recycled paper (86%)
- 0.43 million tonnes cellulose (virgin wood fibres) (14%)

The cellulose pulp is imported from Europe (53%), in particular Scandinavia and Portugal, from Latin America (39%) and United States of America and Canada (8%).[9,10]

Feedstock prices: Average recycled paper price was € 129 per tonne in 2017 and € 79 per tonne in 2018, [9] so an approximate price of € 100 per tonne was used in this study. Average price for imported cellulose (virgin wood pulp) for 2018 was US$ 1.166 per tonne for Northern Bleached Softwood Kraft and US$ 1.037 per tonne for Bleached Eucalyptus Kraft Pulp.[9] A strong increasing trend is observed over the years for imported virgin wood fibres.

The products were:

- 2.2 million tonnes packaging paper and cardboard (of which 0.94 million tonnes corrugated cardboard and 0.64 million tonnes solid board) (74%)
- 0.7 million tonnes graphical paper (of which 0.26 million tonnes newspaper paper and 0.24 million tonnes of print and coated paper each) (22%)
- 0.1 million tonnes sanitary paper (4%)

In 2018 0.6 million were sold into the Dutch market and 2.4 million tonnes were exported, most to Germany, Belgium and the UK.[9]

Product prices: The Dutch wholesale market price for corrugated board (180 g/m$^2$) is € 1,297/tonne ex VAT and solid board sheets (300 g/m2) is € 924/tonne ex VAT. The Dutch wholesale market price for print paper (80 g/m$^2$) is € 855/tonne ex VAT and newspaper is € 500/tonne.[11]

In Gelderland eight paper mills are operational. The key figures of these mills can be found in Table 1.

***Table 1. Paper mills in Gelderland, key figures[12-14]***

| Paper mill | Location | Capacity (tonnes product/year) | Number of production lines | Product type | Feedstock |
|---|---|---|---|---|---|
| Smurfit Kappa Parenco | Renkum | 650,000 | 2 | Graphic paper, packaging paper | 100% recycled paper |
| Papierfabriek Doetinchem | Doetinchem | 70,000 | 4 | Lightweight papers | 100% recycled paper |
| Schut Papier | Heelsum | 3,500 | 1 | High value specialty paper | Imported wood fibres + Local ligno sources |
| Mayr-Melnhof Eerbeek BV | Eerbeek | 150,000 | 1 | White lined chipboard | Imported wood fibres |
| Neenah Coldenhove | Eerbeek | 30,000 | 2 | Print paper, board, specialty paper | Imported wood fibres |
| DS Smith Paper De Hoop | Eerbeek | 360,000 | 2 | Container board products | 100% recycled paper |
| VHP Security Paper | Ugchelen | 6,500 | 1 | Banknote paper | Imported wood fibres, cotton linters |
| Smart Packaging Solutions | Loenen | 65,000 | 1 | Solid board | Recycled paper and Imported wood fibres |
| **Total Gelderland** | | **1,335,000** | **14** | | |

Besides the paper mills in the table, in Loenen museum paper mill 'De Middelste Molen' is active and running on hydro-power. It has a very low capacity.

The main feedstock is recycled paper (around a million ton annually) and to smaller part virgin fibres, which is cellulose pulp from wood, mostly imported from European countries (around 0.2 million tonnes dry matter annually). In addition, Schut Papier uses both non-wood pulp (e.g. cotton linters, flax, sugar cane bagasse, Miscanthus) and all kind of fibrous materials (e.g. rags, tulip residues, tomato stalks) in their end product but in relatively small amounts. Only Schut papier is able to incorporate fibrous materials into their paper products, directly without pulping. All other paper mills can only work with pulp. Setting up of a mechanical or chemical pulping facility will therefore be necessary.

A part of the recycled paper can be obtained from Gelderland: 138,000 ton recycled paper is collected from households and companies,[6] which is about 12% of the demand from Gelderland paper mills (Table 2).
Some companies have a history in wood pulping, or have small scale equipment to produce pulp from non-wood fibrous materials. Additional information is provided below:

*Parenco*
The largest mill, Smurfit Kappa Parenco,[13] uses paper line 1 to produce graphical paper. The most important product is parCal, which has a weight of 45 to 56 gram/$m^2$. It is used for flyers and magazines. Paper line 2 produces packaging paper e.g. fluting and test liner (80 to 120 gram/ $m^2$). The company is trying to improve sustainability. 40 % of the required heat (steam) is derived from sustainable sources. Each $m^3$ water is used at least eight times before it is discharged in the wastewater treatment plant. In this wastewater treatment plant a large part of the organic compounds are converted into biogas. Metals from recycled paper are offered to recycling companies. Small residue fibres are incinerated to produce steam, paper lime (30,000 tonnes/year) is used in building construction. The mill struggles with odour nuisance in the adjacent residential area.

The company has considered to annually use 180,000 ton verge grass as a feedstock, or actually the fibres left after a liquid extraction process carried out by NewFoss and thermo-mechanical pulping by the paper mill.[15,16] Goal was to use 10% of grass fibres in their final product. In 2016 a test of a few hours using paper line 2 has been carried out using 10% ground NewFoss grass fibres and 90% recycled paper. The first trials yielded a lower paper quality, but by using an alkaline pretreatment of the grass fibres the paper quality could arrive at acceptable values.[17] The project was stopped as a result of the shift in ownership of the mill to Smurfit Kappa. The global policy of Smurfit Kappa currently does not include the introduction of non-wood fibres. Besides that, the required pretreatment of the grass fibres makes the process expensive, which can only be justified in periods of high recycled paper prices.

Parenco has pulping experience as they used to produce bleached thermomechanical pulp from softwood from local forests (Gelderland). Up to 2009 many thousands to ten thousand ton of wood has been pulped annually. The company has stopped this activity since thermomechanical refining/pulping is an expensive process step. At present no local virgin fibres are used and the thermomechanical pulping equipment has been dismantled. The company needs the second line to produce packaging paper and the focus is only using recycled paper.

*Schut Papier*
Schut Papier[18] is specialized in niche markets, e.g. paper for artists, coloured paper and paper for technical applications (filter papers). The paper weights can range from 55 to 600 gram/m$^2$. Customers can order already as small as 2 tonnes of paper. The feedstocks are very diverse as well. Non-wood fibres are frequently used, chemical pulps from Miscanthus, cotton linters, sugar cane are used in their products on a regular basis. Specific batches of paper containing fibrous materials, tulip residues, tomato stalks, grass, rags (blue jeans), cacao residues and many more have been produced and can be ordered. Schut is carrying out innovative projects in which organic residues are used as feedstock. The wastewater of Schut papier is treated in the waste water treatment plant from Parenco. Schut Papier is using local virgin fibres as a part of its raw material (exact percentage/fraction is unknown).

*Mayr-Melnhof Eerbeek BV*
Mayr-Melnhof Eerbeek BV[19] is one of the three paper mills in Eerbeek. With 200 employees virgin fibre carton board is produced. It is the largest user of virgin fibres in Gelderland. The reason for the use of this type of pulp instead of recycled paper is the application in the food industry.[20] The use of clean raw materials guarantees food safety. Recycled paper may contain contaminants. One of these contaminants are certain volatile compounds (MOSH and MOAH) from the ink. Mayr-Melnhof has considered to use local wood as feedstock, but is currently importing the virgin fibres. Besides applications in food packaging, the mill produces for the cosmetics and pharmaceutical market. Mayer-Melnhof Eerbeek has experience in on site thermomechanical pulping of softwood.[21] This wood was imported from Belgium. Currently no local virgin fibres are used.

*Papierfabriek Doetinchem*[22] produces white papers, brown papers and semi-crêpe paper, for bags, table covers, napkins, solid board and corrugated board. In this mill 150 employees are employed. No virgin fibres are used.

*Neenah Coldenhove* (Eerbeek)[23] produces dye sublimation printing paper, heat transfer papers, high barrier coated laminates, digital pigment transfer paper, sterile barrier paper for sterilisation packaging solutions and boards. It has 130 employees. Currently no local virgin fibres are used.

*DS Smith Paper De Hoop* (Eerbeek)[24] has a paper line for the production of 95-140 gram/m2 paper and a second production line for 120-260 gram/m$^2$ paper. It employs 185 people. No virgin fibres are used.
These three mills in Eerbeek share a wastewater treatment plant. In this plant a part of the organic matter is converted into biogas, which is used as fuel by DS Smith Paper De Hoop. It also produces elemental sulfur which is used elsewhere. Chalk (calcium carbonate) is produced and used in agriculture. The clean water is reused by DS Smith Paper De Hoop.[25]

*VHP Security Paper*[14] is small, but nevertheless has 130 highly qualified employees to produce banknote paper and other security papers. Because of their end-products access to the facility is restricted. The cotton linters used in some of their products is bleached and pulped onsite. A product containing hemp as replacement of cotton linters was produced and marketed as "Dutch Cotton" by VHP. Local virgin fibres such as hemp are only used on a few occasions when clients order it.

*Smart Packaging Solutions*[26] (former Solid Pack) produces solid board that can be printed on and are printed on in the mill. The markets are packaging for food, flowers and industry. Depending on the market, the feedstock is recycled paper or virgin fibres (from wood). The virgin fibres are FSC® certified, which means that the trees are from forests (outside the Netherlands) that are managed according to certain rules and that for each used tree three or four new trees are planted. The mill has 175 employees and an annual turnover of 50 million Euro. Solid Pack has produced solid board containing grass fibres in the past. A pilot line for an extrusion based mechanical pulping technology was used to test several other non-wood fibrous materials.

### 3.1.2 Lignocellulosic biomass resources in Gelderland and how they are currently used

The term lignocellulosic is used to describe material that is mostly composed of cellulose, hemicellulose, and lignin. Lignocellulosic biomass is the most abundant type of biomass and includes a wide variety of different biomass types including grasses, wood, energy crops, and agricultural residues and municipal wastes (see Table 2). The list includes both primary sources from forest and agriculture as well as residues from forestry, agriculture and industry.

***Table 2. Types of lignocellulosic sources[28]***

| Biomass category | Biomass type detail | General definition | Specific examples |
|---|---|---|---|
| Forestry biomass | Woody biomass | Biomass from forests and other wooded land including tree plantations | Softwoods and hardwoods |
| Energy crops | Woody/herbaceous lignocellulosic biomass | Biomass from agricultural production activities | Energy crops (short rotation coppice such as willow and poplar and grass species such as Miscanthus, bamboo and switchgrass) |
| Fibre crops | Woody/herbaceous lignocellulosic biomass | Biomass from agricultural production activities | Hemp, flax, jute |
| Primary forestry residues | Woody biomass | Cultivation and harvesting / logging activities in forests and other wooded land | Available volume of felling residues (branches and roots) |
| Agricultural primary residues | Solid agricultural residues | Biomass from agricultural cultivation and harvesting activities | Straw, corn stover, stalks, stems, leaves |
| Primary residues landscape | Woody/herbaceous lignocellulosic biomass | Biomass from trees/hedges/grasslands outside forests and agricultural land incl. public green spaces, recreational areas, road side verges, waterways, nature conservation areas | Biomass residues/solid biomass resulting from maintenance activities (e.g. verge grass and woody cuttings from recreational lands, nature conservation areas, landscape elements) |
| Secondary forestry residues | Woody biomass | Biomass coming from wood processing, e.g. industrial production | Woodchips, sawdust, black liquor |
| Secondary agricultural residues | Solid and wet agricultural residues | Processing of agricultural products, e.g. for food | Processing residues (e.g. shells/husks from seed/nut shelling, sugarcane bagasse, potato peelings, beet pulp). |
| Tertiary residues industry | Organic waste from industry and trade | Biomass from industry and trade, excl. forest industry | Recovered demolition wood, textile waste, pallets |
| Tertiary residues households | Organic waste from private households/gardens | Biomass from private households/gardens | Waste paper, discarded furniture |

To quantify the primary production of lignocellulosic biomass in Gelderland, several data sources have been combined (see Table 3). Nature and forests areas are defined and appointed by governments and the areas of nature and forests are taken from the nature type allocation for the Dutch Subsidy Scheme Nature and Landscape (SNL). Urban green refers to mainly trees, shrubs/bush and rough grass and lawns in the built-up areas, managed by municipalities. The quantity of urban green is based on the average available quantity per inhabitant in the Netherlands according to the Benchmark for Urban Green.[29] Other urban green - not maintained by municipalities - is not included in the estimation, since there are no clear statistics of its availability. A test study using GIS data however indicates roughly a similar quantity of urban green is maintained by households, sport associations, housing corporations and private companies. Quantities of landscape elements, being mainly elements such as solitary trees, tree rows and hedgerows, were based on a GIS analysis by de Jong et al. (2009).[30] The area of road sides is estimated by multiplying the length of roads per road type according to the data of CBS (2018) by an estimated width of 4.5 m for local roads, 8 m for regional roads and 13 m for national roads.[31] The quantities were combined with average productions according to de Jong et al. (2012)[32] and de Vries et al. (2008)[33] to calculate the total production per year. The production of straw is based on the regional data of CBS (2017).[34] Branch wood production from agriculture (from fruit production) is taken from Oldenburger et al. (2017).[35]

Grass from (diary) farms (approx. 1.5 Mton ds per year) is not included in the table, since the use for fibres could compete with its use for feed.
Bole wood from production and natural forest is the largest potential source of lignocellulosic biomass. Total bole wood production is estimated at 367 ktonnes per year (Table 3). Grass from nature and road sides is the second largest source, amounting an estimated 166 ktonnes per year. Branch wood, mainly from forest but also from landscape elements, urban green and agriculture contributes significantly to the total available amount of biomass. Production of straw, mainly from agriculture, and from nature, may seem small compared to other sources, but may still be useful quantities.

***Table 3. Estimated primary production of biomass (tonne dry matter per year) in Gelderland***

| | non farmland grass | straw | bole wood | branch wood | reed rough |
|---|---|---|---|---|---|
| agriculture | - | 27,241 | - | 9,912 | - |
| landscape elements | - | - | 28,767 | 20,459 | - |
| nature | 70,169 | 2,361 | - | - | 17,088 |
| roadsides | 82,842 | - | - | - | - |
| urban green | 13,015 | - | 4,925 | 13,389 | 68 |
| natural forest | - | - | 130,690 | 32,672 | - |
| cultural forest | - | - | 6,924 | 3,339 | - |
| production forest | - | - | 196,272 | 49,068 | - |
| **Total** | **166,026** | **29,602** | **367,578** | **128,839** | **17,155** |

Statistics for the use of biomass are not available for the province of Gelderland specifically. Data on the use of biomass on national scale may however give a good indication for the situation in Gelderland. Grass from roadsides in the Netherlands has been used for cattle feed in the 1970's but around 1980 demand from farmers decreased and grass more often was deposited at waste dumps. From the late 1980's on, composting has been the main destination of grass from road sides.[36] Grass from nature areas is for a large part used in farms, both for cattle feed and for litter in stables. A substantial proportion has been allocated as nature area in recent decades. The grass from these lands become less attractive to farmers as they become less nutritious and the production decreases through active removal of nitrogen through biomass removal.[37] Therefore both roadside and nature managers are looking for alternative uses for their grass.[38] Statistics on the use of straw are not known, but it is commonly known that straw is largely used as litter in stables. Wood increment from forests is only partly harvested. From Schelhaas et al. (2014) it is clear that on average 3.4 $m^3ha^{-1}yr^{-1}$ is harvested on an increment of 7.5 $m^3ha^{-1}yr^{-1}$.[39] A large part of the increment stays unharvested, leading to an increasing standing stock. Function allocation plays a large role for the province of Gelderland, as approximately 55% of the forests is actually allocated as production forest. Branch wood from forests is hardly harvested in the Netherlands. However, branch wood from agriculture, landscape elements and urban green is mainly composted, left behind or used for energy, although an increase in demand for energy is expected.[40] The harvested wood from forests is used in the sawmills and for energy and is exported in approximately equal proportions. The wood from the build environment and landscape elements is largely used for energy, both for round wood and chips.

In 2010 the use of wood for paper (including imported paper and pulp) in the Netherlands was 50% of the total industrial wood consumption (excluding use for energy), declining to 45% in 2017. Including the use of wood for energy, the Dutch proportion of wood for paper was 34% in 2017.[41] There are no specific statistics of the wood consumption specifically for Gelderland available.

## 3.2 Defining the New Business Case

### 3.2.1 Integration of alternative local fibre sources to local paper industry in Gelderland

The current paper industry relies on import of pulp made from virgin wood fibre. The circularity objectives put pressure to find local bio-based alternatives and create added-value to underutilized biomass resources. This calls for utilizing local lignocellulosic sources as much as and as long as possible in materials before directing for energy use. Thereby, they support initiatives for the use of local fibre-rich biomass for paper in order to create new value. In this way, the use of locally available or cultivated biomass for fibres can make a significant contribution to the future mix of feedstocks for the paper industry. Furthermore, this allows to keep the carbon stored in a product and by possibility of recycling several times it can stay longer in the cycle. This is also supportive of reaching targets to combat climate change.

The paper industry in the Netherlands is a frontrunner in recycling. 84% of the paper and cardboard marketed in the Netherlands are recycled.[42] Paper fibres can be recycled about six to seven times. It is therefore always necessary to supply fresh and stronger fibres.[43] Since the digital revolution and the increase of online ordering more cardboard and less graphical paper is needed. The result is that the recycled paper contains more cardboard and therefore less strong fibres. There is a need for using virgin fibres in paper making to achieve the desired quality. The current virgin fibre demand is supplied by imported wood pulp mainly from Europe and America. These virgin fibres do not need to be only fibres from wood, but can be fibres from grasses and agricultural and forestry residues.

The Netherlands is strong in agriculture and has a long history in utilizing fibres from plants. Furthermore, significant amount of grass and forestry residues are available from nature management. There is also increasing interest in locally growing crops such as Miscanthus and hemp. There are a number of new initiatives in processing these sources and for utilizing the fibres.

However, processing and mobilizing locally available or cultivated lignocellulosic biomass can be more difficult. There is requirement for effective separation and conversion techniques as well as cooperation with the paper industry. This is important in achieving economic feasibility as well as having a low environmental footprint. These fibres will have different characteristics than the wood fibres and adaptation of the current paper industry will be necessary.[44] The requirement for a constant quality could also be a problem for these sources.

Outside the scope of this paper, there are additional chances to improve circularity of paper industry in Gelderland through valorising their residues and waste streams:

1. Paper sludge

The fibres in paper and cardboard can be recycled approximately six to seven times, depending on the type of paper being produced. The fibres are then unsuitable for recycling and are separated as paper sludge during the pulping process. The paper sludge currently find use in cement industry or as alternative fuel in boilers. An alternative way to create more value, increase circularity and reduce dependence on fossil resources is pyrolysis of paper sludge into bio-oil. Alucha[45] is working on this technology and application on paper sludge. With this technology they separate the organic from the inorganic matter, so recovering minerals. From the organic matter pyrolysis oil can be produced. This pyrolysis oil can be used in boilers for energy but also converted to liquid biofuels or green chemicals.

2. Rejects

Paper rejects are the coarse residues from the pulping process. In addition to fibres, there is a considerable amount of (non-recyclable) plastic in the material. These rejects are currently incinerated or used as fuel in waste-to-energy boilers. An alternative way to create more value, increase circularity and reduce dependence on fossil resources is to make bio-composites. Cellulose fibres and plastics in rejects can be converted into Wood Plastic Composites (WPCs) by extrusion. WPCs are used in, among other things, fences and transport pallets. Another alternative is production of solid recovered fuel with high energetic value that allows replacing fossil fuels.[46]

3. Process water

The process water from paper mills that process recycled paper naturally contains organic matter (e.g. fatty acids) that can be converted into biopolymers (PHAs).[47] This conversion is carried out by micro-organisms within mixed microbial cultures and, in addition to the production of the polymers, also results in the purification of the process water, which can be reused within the paper mill (closed water cycle). The biopolymers, which are stored as microbial fat within the microorganisms, can be extracted from the biomass in the following steps for further processing into bioplastic material with different applications (e.g. films, packaging, etc.)

### 3.2.2 Technology required and expected future developments

*Pulping*

Pulping is separating cellulose fibres from wood or other lignocellulosic biomass. Several pulping processes exist which can be broadly classified into mechanical and chemical pulping.[48] Mechanical pulping is used for products that require less strength such as newsprint and paperboards. Varieties of it exist being thermo-mechanical pulping and chemi-thermomechanical pulping. Chemical pulping is used for products that need to be stronger. Production costs are higher. The Kraft process is the dominant chemical pulping method with the sulfite process being the second. Other types include alkaline pulping, organosolv pulping and acetosolv pulping.[49] Currently, in The Netherlands pulp is mostly imported. Only 37 ktonne pulp production in the Netherlands is reported for 2018[41] (where 425 ktonne virgin pulp per year was used in paper production).

*Paper and board making*

In Gelderland most paper and board is produced from recycled paper. The production process starts with mixing the recycled paper with water in the pulper. A carefully designed blend is made from various waste paper grades in anticipation to arrive at the desired paper grade. The pulp is washed and cleaned, using filter techniques, to remove contaminants such as sand, staples and plastic. The ink is removed in an de-inking installation, based on flotation. An option is to bleach the pulp with oxygen, hydrogen peroxide or ozone to create a whiter appearance. Subsequently the functionality of the fibres is improved in a refiner and additives are added such as dyes and compounds that improves the wet-strength. In case pulp from virgin wood fibres are used, the pulp is mixed with water, refined, mixed with additives and introduced in the paper machine for dewatering. The pulp containing 0.5% fibres and 99.5% water is dewatered in the paper machine by spraying it on a wire to create a web of fibres. First it is dewatered to 50% water. The remaining water is removed in the press section and subsequently in a heated glazing cylinder, which heats the backside of the paper with hot air and creates the typical smooth side of some paper types. The paper is rewound on reels to make rolls.

*Capabilities of current paper and board producers*

It is unlikely that mechanical or chemical pulping processes will be installed in the Netherlands in the near future, because import of pulp is cheaper than pulping of uniform wood chips within the Netherlands. Furthermore, there is a large supply of recycled paper. So installation of new facility for pulping local wood resources is not commercially attractive.

Equipment of Schut paper is suitable for processing of non-wood fibres. They are currently producing specialty paper using fibres from cacao shells, grass, Miscanthus, tomato stems and used jeans.[18] VHP Security Paper uses a 'Hollander', which is a refiner that can carry out a mechanical pulping e.g. of cotton and hemp.[14] Parenco mill in Renkum had a thermo-mechanical pulping (TMP) facility, which is now dismantled. They considered to use their second production line for producing TMP fluff from wood, Miscanthus or grass.[15-17] The project was stopped as a result of the shift in ownership of the mill to Smurfit Kappa. Due to an increased demand the second production line, is currently used to produce cardboard. Smart Packaging Solutions in Loenen has produced cardboard from cut grass from areas of Natuurmonumenten.[51] They stopped with it due to problems with accumulation of contaminants and other technical problems. Mayr-Melnhof Eerbeek BV is or has been using a mechanical pulping plant to produce pulp from poplar wood (90%) and softwood (10%).[50] Currently use of local lignocellulosic sources is low in Gelderland. The decision to increase use can be triggered by increasing price for recycled paper or pressure to reduce import of virgin wood fibres.

*Examples of current applications with lignocellulosic biomass*

*Huhtamaki - Egg boxes with grass fibres*
Huhtamaki in Franeker (Friesland) produces moulded fibre products such as egg boxes, egg trays and fruit boxes. The company is using 30,000 tonnes recycle paper annually to produce these products. Since a few years, a part of the egg boxes is produced from a mixture of grass fibres and recycled paper, each 50% by weight.[52] These egg boxes, called GreeNest, are slightly more expensive and are used for organic or free-range eggs. The packaging offers the same protection properties. The egg boxes are available in supermarkets among others Albert Heijn and Jumbo. They are also sold abroad.

This application is taken as an example in this project to assess potential impacts of use of lignocellulosic resources in paper/board industry. More information is provided in section 3.3.


***Figure 1. Egg box from Grass (Huhtamaki)***

*Packing for vegetables using tomato plant fibres*
The fibres from tomato and bell pepper plants can be used to make board. [53] In particular, this is popular for packing board for tomato and bell peppers. Normally these plant residues are composted, but using it in board implies a longer use. Before use the stems and leaves are ensiled to partly dewater the material and to bring the fibres at the right quality. Clips and pieces of rope are removed. Again recycled paper and fibres from tomato and bell pepper stems and leaves are mixed to produce a suspension in water (pulp). This pulp is the basis for the production of solid board. Tomato producers, research organisations (WFBR), The Greenery and paper mills work together in this development.[54]

Large amounts have been processed by Solidus Solutions. 85 million kilos of tomato plants grow annually on around 1800 hectares in the Netherlands. Per hectare of tomato plants, 100,000 tomato boxes (6 kilograms of trays) can be produced. This year's cultivation, therefore, also provides the packaging for the following year. The cardboard equivalent to these 100,000 trays can of course also be used for other types of packaging. It is shown that this innovation can provide a $CO_2$ emission reduction per ton of cardboard (around 200 boxes for 6 kilograms of tomatoes) that can amount to 54,500 g $CO_2$ eq.[51]

***Figure 2. Solid board made from tomato stalks (Smart Packaging Solutions)***

However, these projects are not running on large scale anymore. According to René Kort, CEO of Schut Papier, this is due to the fact that tomato plant fibres have a higher price than the regular raw materials. All involved parties still work in projects on this subject to give it a next try.[55]

*Local lignocellulosic sources for specialty paper (Schut Papier)*
Schut Papier has developed together with knowledge centers, universities and companies in the network, paper made from several lignocellulosic sources as substitute of virgin wood fibres. Examples include the residuals of plants such as paprika and tomato, grass, Miscanthus, used jeans and cocoa shells.[56]

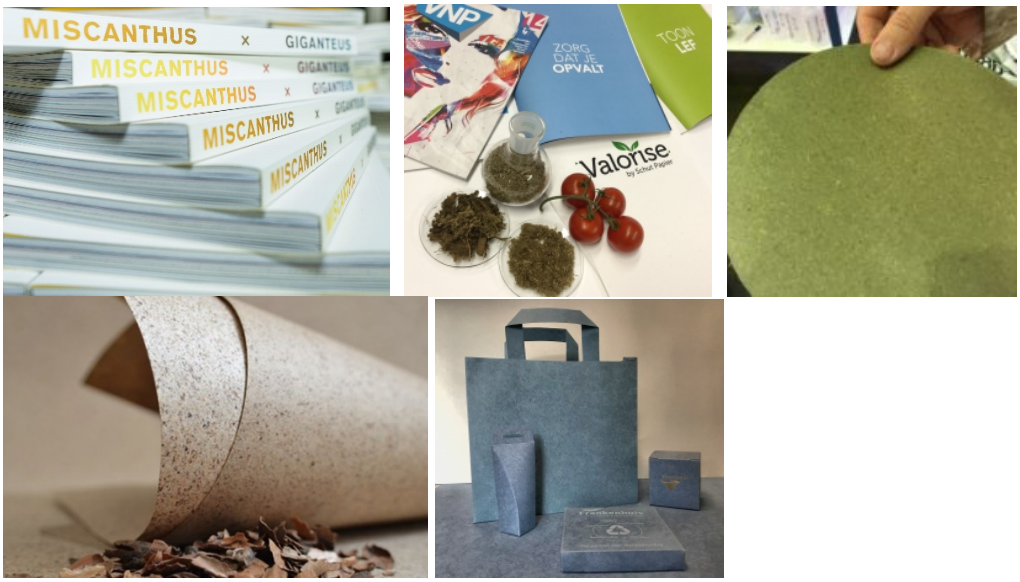


***Figure 3. Specialty paper from lignocellulosic resources (example including use of Miscanthus, tomato stalks, grass, cocoa shells and jeans)***

*New initiatives for lignocellulosic biomass growing and processing*

There are new initiatives in the Netherlands to grow and process lignocellulosic biomass. These technologies allow separation of fibres from local lignocellulosic resources that can be used as input by the paper industry. There are also new initiatives in growing new types of lignocellulosic biomass in the Netherlands such as hemp, flax and Miscanthus.

*NewFoss*
NewFoss[57] developed a biorefining process suitable for converting 100% of the residual biomass such as grass and agricultural residues into high value products. They have a full scale testing facility in Uden able to process up to 10 tonnes/day grass from roadsides or nature. The process converts non-woody biomass into two valuable product streams: an inert lignocellulosic fibre and an aqueous juice containing the separated minerals, salts, amino-acids, protein and other cell contents; the grass juice. This mild extraction process uses the microbes already present on the organic feedstock. The process takes place at ambient conditions and does not use any chemicals or other additives. NewFoss just accelerates and controls a natural process. The lignocellulosic fibre are predominantly used in the paper- and cardboard industry. The grass juice which is a side product of fibre production is rich in easily digestible organic components. When digested in a standard anaerobic digester it yields biogas.

*Grassa*
GRASSA! develops (mobile) refining machines which can refine grass and other green residual flows such as sugar beet and tomato leaves, vegetable processing residues such as broccoli stalks and lettuce into new high-quality products.[58] It is based in the Bio Treat Center in Venlo. Mobile, small-scale modular process installation has been built with a capacity of 1-5 tonnes green fresh materials per hour. In biorefining, the green raw material is first crushed and pressed; the juice is separated from the fibres. The fibres, with a part of the proteins present in the grass, are extremely suitable as feed for cows, and can be packaged airtight, so that they are preserved. The compressed fibres can alternatively be used in the paper and board industry. Part of the nutrient comes with the juice. These are proteins, sugars and minerals. The juice can then be further processed by separating the proteins from it and concentrating. The liquid that remains is called 'whey', analogous to the milk industry. The 'whey' can also undergo further treatment and be separated into phosphate, sugar-rich and mineral-rich fractions.[59]

*Miscancell*
Miscancell produces cellulose fibres from miscanthus for the paper industry in a sustainable way, preferably without residual waste.[60] The cellulose is then available for paper manufacturers as well as for chemical industries. Miscancell has started her pilot plant at the Kleefse Waard Industrial Park in Arnhem. It is located at the port of Arnhem, which promotes supply of Miscanthus by waterway transport. Miscanthus is a perennial crop that can be harvested annually over a period of 20-25 years. Other advantages of the crop are that it doesn't need weed control or other pesticides. There's no need for fertilization, neither for irrigation. It can be processed directly after harvesting without intermediate processing for further production. In this way Miscanthus is already used for bioenergy and groundcover in stalls.

*Millvision*
Millvision[61] develops biobased materials and products in order to achieve a more sustainable society, extract the raw materials (often residual flows) from the region and produce as much as possible in the region itself. Millvision has its development center on the Dombosch industrial site in Raamsdonksveer. It is involved in various projects such as Grasgoed, Grassification and Growing a green future.

Giving clippings a second life as a sustainable product is the goal of the GrasGoed project.[62] There are 12 partners working together in GrasGoed to come up with solutions to strengthen the links in the chain from grass to product. Millvision is involved in product development, in creating new prototypes using these raw materials. 8 potential products are evaluated for commercialization, including grass paper and grass cardboard.

*HempFlax*
HempFlax[63] is a leading producer and processor of industrial hemp. Their cultivation takes place in the Netherlands, Germany and Romania and processing takes place in factories located in Oude Pekela, Netherlands and Alba Iulia, Romania. Hemp can be grown on in the poorest soil and in almost any climate. It grows very fast, doesn't require chemicals (fertilizers/pesticides) and requires very little water. Hemp is extremely versatile and the different parts (seeds, stalk, leaves, roots) of the plant can be utilized for different purposes. Hemp fibres can be extracted from the stalk and used in many industrial applications such as the paper, textile, building and automotive industry.

*Dun Agro Hemp Group*
Dun Agro Hemp Group[64] is a group of hemp industry professionals operating in the Netherlands. They handle the entire value chain, from field to primary processing and end product manufacturing. The in house designed processing mill has a capacity of up to 8 t/h while requiring only a modest amount of energy. The processing mill is scalable without any change in quality. They produce CBD (cannabidiol) from leaves, hemp hurd and hemp fibre mostly use in non woven applications.

*Van de Bilt zaden en vlas bv*
Van de Bilt zaden en vlas bv[65] is located in Sluiskil, Netherlands within reach of the three major ports of Antwerp – Vlissingen – Zeebrugge. The company has its growers in the Netherlands, Belgium and France. The flax supplied to the company is processed in its scutching mill. Fibres grow around the woody cylinder in the plant's stem. Processing breaks down the composition of this woody cylinder and allows the plant to be split to extract long fibres, short fibres and by-products, including the woody shives. These woody shives are collected separately in bulk containers for further processing into particle boards (Linex, Faay), bedding for horses and cattle etc. The short fibres are cleaned and pressed to form bales before being sold. The long fibres for linen textile use are cleaned mechanically to remove any fine woody particles and then pulled through various combs – a process also known as hackling – to make the flax finer. Seed trading is one of their key activities. They breed, produce and sell propagating material for fibre flax and oil flax.

*Research into new applications*

Several research projects focused on valorising lignocellulosic resources for fibre. GlueReed[66] worked on developing an ecological friendly fibre boars based on reed that is liberated from the wetlands by Natuurmonumenten. Ecocoboard[67] project developed an innovative method to produce a new, high-quality board material from coconut husks. Cocoa shell biorefinery project[68] works on separating the cocoa shells into lignin and fibre fractions and finding high-value applications for these fractions. With Schut Papier the fibres were processed into specialty paper with a pulping process without the use of sulfur.

### 3.2.3 Expected impact on economics, environment, society and circularity

There are different possibilities for markets for the use of local lignocellulosic biomass in the paper industry. A distinction can be made between niche and bulk markets, and between low value and high value products (see Figure 4). For low value products the key is price, for high value products the key is quality. A niche market is a small, specialized market for a specific product. When a certain product is more expensive than the regular ones, it has to have special features for a specific group of customers. These specific features may be a more sustainable production process, improved circularity or use of local resources.

| | **Low value** | **High value** |
|---|---|---|
| ***Niche*** | Grass egg boxes,<br>tomato stalks board | Specialty paper using<br>e.g. Miscanthus, grass |
| ***Bulk*** | Regular packaging cardboard | Standard white print paper |

***Figure 4. Overview of product market – value combinations for use of alternative lignocellulosic biomass in paper industry***

The production of paper and cardboard partly using local lignocellulosic biomass has already been done in niche applications by several parties. The challenge is to do this at a larger scale at commercially attractive prices for bulk products such as regular cardboard or print paper. The examples of egg boxes using grass fibres and packaging boards using tomato stalks are examples for low value, niche market applications. They need to meet the same functionality as conventional cardboard but customers are willing to pay a green premium for the associated sustainability benefits. For low value markets for replacement of imported virgin wood fibres and recycled paper by fibres from lignocellulosic biomass, product properties must be maintained, while having a limited or no effect on the costs.

The specialty paper Schut Papier is producing paper pulp using alternative lignocellulosic biomass sources such as Miscanthus and grass. This is an example for high value, niche market application. Schut paper industry is playing a growing role in the circular economy in Gelderland. Not in volumes yet, but in product development from these sources and waste streams such as used jeans. The paper produced is not white clear but the fibres of the biomass can be seen in the final product. This special look is however appealing for certain customers. "The added value in sustainable experience must be seen and endorsed financially by end users." concludes René Kort, director of Schut Paper.[69]

*Expected impact on circularity, economics, environment and society*

*Impact on circularity*

Resource efficiency

- Less imported virgin fibres from wood and more locally harvested residual materials are used (grass from road sides etc.). This means improved land use efficiency: less land used for wood production abroad whereas residual resources do not require land use.
- As for the virgin lignocellulosic sources such as Miscanthus, flax and hemp, they can be grown on land which is not suitable for other kinds of agricultural production and can be harvested annually, grow fast, and do not require chemicals and require little or no irrigation.

- According to NewFoss[57], the grass juice which is a side product of fibre production when digested in a standard anaerobic digester to biogas results in enough energy to meet the entire energy demand of the production installation. And there is even some energy left to supply to adjacent energy consumers such as houses or offices. Furthermore, again according to NewFoss, the water used in the process is cleaned and recycled completely. So the process is 100% circular concerning water and energy use.

Recycle efficiency

- Paper and cardboard are recycled on a large scale in the Netherlands and worldwide. How does paper made from alternative fibres, e.g. grass, would influence the recycle process? This is an important question being researched as the use of alternative fibres must not adversely affect paper recycling.[70] According to Huhtamaki, their GreeNest product made with 50% grass fibres can be 100% recycled together with old paper.[71]

*Impact on the economy*

For the province Gelderland, it is more suitable to focus on niche markets, such as specialty paper, with special characteristics and packaging boards with sustainability and circularity benefits. When these products are made from grass from clippings from roadsides, costs for collection and transportation are important for feedstock price. When the products are made from crops such as Miscanthus, then combinations of cultivation, harvesting and transportation will be essential for the feedstock price. An advantage is typically the low chemical and irrigation requirement for these type of crops. Improved technical processing efficiency and further increase of scale to achieve economies of scale would be influential for the processing cost of extracting fibres from the lignocellulosic materials. The valorisation of processing residues for example producing biogas from the grass juice will be significant to generate additional revenues or reduce process costs.

For the province Gelderland the paper industry is important for economic gains and employment. But, the province is lagging behind in income per capita compared with the rest of the Netherlands (see paragraph 3.2.4). Therefore an increase in bioeconomic activities and related employment and revenue created will be significant for the province.

To rely more on domestic resources instead of imported ones, means less dependency on highly volatile demand for pulp and recycled paper. In the recent past there have been significant fluctuations in demand, especially due to demands from China. In the future, demand for fibres may increase, both nationally and internationally, due to the transition towards a biobased economy. Therefore, a shift towards more domestic resources may be part of risk management.

*Impact on the environment*

Crops like hemp and Miscanthus capture more $CO_2$ than trees, mainly because they grow much faster. Miscanthus absorbs about 30 tons of $CO_2$ per hectare per year, which is four times more than an average European forest.[72] According to Schut Paper, calculations show that 17% $CO_2$ reduction is possible in paper production through reuse of local, residual materials such as crop residues from horticulture. All extra transport for supplying standard paper raw materials from abroad is included as well as opening up and bleaching of cellulose from wood.[69] Huhtamaki claims by replacing half of the recycled paper with grass fibres the carbon footprint of the products has decreased by 10% and the water consumption by 50%.[52]

Converting the underutilised lignocellulosic biomass into material allows the $CO_2$ absorbed by plants to be stored which would otherwise be emitted back to atmosphere. By application in paper the $CO_2$ absorbed can stay longer in the cycle by recycling. However, if agricultural residues or local wood will be utilised it is important to consider sustainable harvesting levels not to have a negative effect on soil fertility.[40,73]

*Impact on society*
Preserving or increasing employment in the province Gelderland is very important as shown in the BERST study in section 3.2.4. Introducing alternative fibres, the main paper industry will basically stay the same but there will be increased employment for the collection and transport of local biomass resources (international transport will decrease, however). Furthermore, pre-processing of the local lignocellulosic biomass to convert it into fibres that can be used in the paper/board industry will yield extra employment.

### 3.2.4 Enabling factors and barriers

The BERST study (BioEconomy Regional Strategy Toolkit)[74] structures data which is of interest to estimate regional potential for the development of a biobased economy. The definition of a biobased economy in this study is: "In the bioeconomy, biomass resources are transformed into competitive bioeconomy products. The total bioeconomy includes: the traditional (100%) biobased sectors such as agriculture, horticulture, forestry, fisheries, food & feed, and pulp & paper; and the new biobased sectors such as biotextile, biochemistry, bioenergy and biotechnology."[75]

Figure 5 provides an overview of bioeconomy readiness for the province Gelderland.


***Figure 5. Bioeconomy readiness wheel for the province of Gelderland (2016)[74]***

The wheel shows the bioeconomy readiness for Gelderland (in 2016) compared to the rest of the Netherlands. The inner circle of this figure gives the key criteria that describe the regional bioeconomy. The outer circle gives the indicators that measure a specific criterion. Each indicator has the same weight. Yellow is (close to) average, green is above average (dark green is much higher), orange is below average (red is much lower), and grey means no data available.

Income per capita in Gelderland is much lower than average in the Netherlands. Therefore an increase or at least the maintenance of employment in this region is very relevant. Biomass availability is much higher than average in the Netherlands, especially biomass availability from forests. There are more bioeconomy firms in Gelderland than average in the Netherlands, see also Figure 6 which shows sectoral employment as % of total regional employment in Gelderland compared to the national average (value 0 is the national benchmark value; the blue line shows how far the region deviates from the national average).

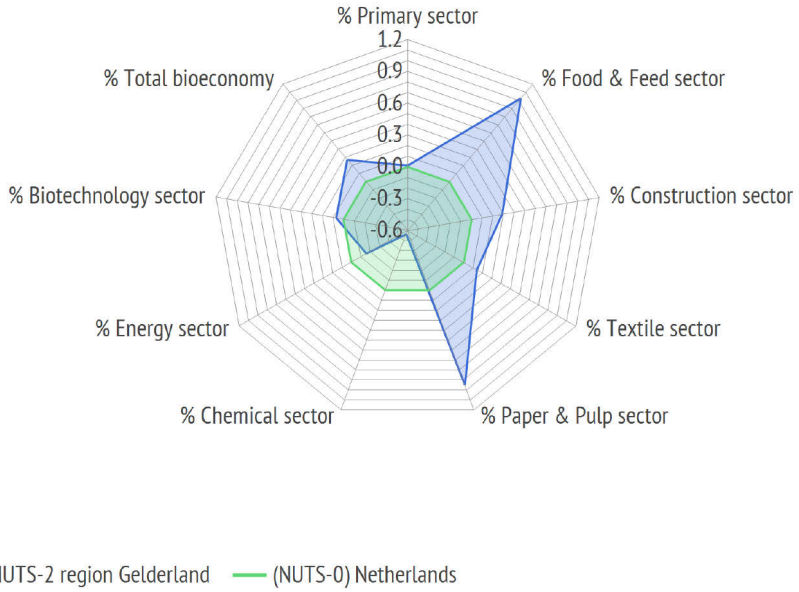


***Figure 6. Employment structure of bioeconomy sectors in province of Gelderland (2016)*** [74]

In the province Gelderland there is more than average employment in the food and feed sector and in the paper and pulp sector, both sectors are traditionally 100% based on biomass feedstock. The employment in the biotechnology sector (i.e. in the R&D) is above average, and employment in total bioeconomy (i.e. all the distinguished bioeconomy sectors together) is even more.

Compared with other regions in the Netherlands, the province Gelderland has a comparative advantage in biomass availability. However, compared with some foreign regions, e.g. the region Länsi-Suomi in Finland, Gelderland has a much lower biomass production. The forestry biomass production in Gelderland is 198 kg/capita, whereas in Länsi-Suomi it is 20,397 kg/capita. In forest rich countries, e.g. in Scandinavia they have an advantage due to economies of scale. Despite transport costs, the price of imported forestry biomass is cheaper than locally produced forestry biomass. Production costs are high locally due to, among others, high harvesting costs of local material.[40,73,76,77]

In order to increase the volume of applications the use of local resources have to become cheaper e.g. by improved technical processing and increasing awareness of customers on sustainability and circularity benefits. The use of local virgin fibres also allows security of supply and reduce reliance on imports. Upscaling the use of local resources is in line with the ambitions of the province of Gelderland and they published a call for initiatives.[78] Scale up will only take place when the whole value chain is present and willing to move and invest. This is still problematic in Gelderland:

- Pulping industry is missing in the province, and is very limited in the Netherlands.
- Local biomass resources availability are relatively small compared to the world market. However, Gelderland is the most wooded area in the Netherlands. Therefore in Gelderland there has already been an economy based on lignocellulose. However, due to nature protection, local wood has become limitedly available or sourced by Gelderland industries. However, it should be considered to grow crops like Miscanthus or hemp. Production in the Netherlands is still small-scale, but there is scope to grow much more.[79]
- Local lignocellulosic biomass is not efficiently collected yet. Therefore, this should be organized first, mainly improve collection of residues from forests, grass from roadsides, and residue streams from agriculture.
- The capacity of Schut Papier is limited and other large paper companies do not have the ambition yet to work with other raw materials, or do not have the equipment and the knowledge on the more novel processing technologies to extract fibres from alternative lignocellulosic biomass resources.

The production costs of paper and cardboard products made of local resources are still higher than the regular product, therefore a premium price has to be paid. This frustrates upscaling. "If raw material prices for, for example, regular cardboard packaging are low compared to the use of residual biomass such as tomato stalks, then customers are still hesitant to opt for the latter solution." says René Kort, director of Schut Paper.[69] In spite of the higher costs, bowls made from tomato stalks and egg boxes made of grass are on the market already, and this shows that there is a business case, even though it is still a niche market. Part of the business case is the story of a local product. Moreover, increased attention for sustainable and circular production is important here. Moreover, transition towards a circular and biobased economy, gets increased attention on a local, national and international level.

Finally, worries about soil fertility keep much of the potentially available residual biomass from forest and agriculture from entering the markets. When the biomass is harvested, nutrients and fibre are taken away and this will affect the soil quality. The effect of utilising this biomass for paper industry depends on what is done with it currently (e.g. whether it is burned, left to rot, or composted).

### 3.2.5 Enabling and restricting framework, governance and policy

The description of the policies at European, national and provincial level may lead to the conclusion that the frameworks are there, are aligned on the different levels and are complete. The challenge now is to bring the missions into practice, to realize the bio-economy, create new perspectives for regional economies in balance with the planetary boundaries. Europe has been leading in ambitious strategies and programs on bio-economy. Large knowledge and innovation programs exist to invest in developing knowledge on technologies, on the potential of various forms of biomass and the valorisation in different kinds of production lines. The Bio-economy Stakeholder Panel, consisting of stakeholders from universities, industries, civil society and regions, have concluded in the Manifesto report that more attention should be given at putting the expertise in practice, reach out for the civil society and bring the ideas and pilots further into full scale investments.[80]

There have been new concepts and frames developed, which are relevant for a proper implementation. At all levels of policies, there is a growing attention for the circular economy. Regions have determined their Research and Innovation Strategies for Smart Specialization (RIS3) and have developed triple helix approaches. These triple helix networks of governments, industries and knowledge institutes are being extended to quadruple helix networks in which also civil society is engaged.[81] Regional innovation systems (RIS) are being challenged to develop innovative solutions for the regional and metropolitan problems, such as climate change.

### 3.2.5.1 EU level

*Bioeconomy strategy*

The updated Bioeconomy Strategy (2018)[82] aims to accelerate the deployment of a sustainable European bioeconomy to maximise its contribution towards the 2030 Agenda and its Sustainable Development Goals (SDGs), as well as the Paris Agreement. The update proposes an action plan with 14 concrete measures based on three key priorities:

1. Strengthen and scale up the bio-based sectors, unlock investments and markets
2. Deploy local bioeconomies rapidly across the whole of Europe
3. Understand the ecological boundaries of the bioeconomy

Regarding the local bioeconomies, EU favours a systemic approach, which addresses bio-based innovations in farming and in development of new chemicals, products, processes. Also supports development of value chains for bio-based markets in rural areas, with involvement and increased benefits for primary producers. Also there is consideration for new opportunities for the forestry sector in view of replacing non-sustainable raw materials in construction, packaging with bio-based materials and for providing more sustainable innovations in sectors such as forestry-based textiles, furniture and chemicals, and new business models based on the valuation of forestry ecosystem services.

*Renewable Energy Directive*

On the other hand, Renewable Energy Directive of the European Commission[4] incentivizes the use of biomass for energy use. This is, however, not in line with circular economy. Using biomass for materials allows biomass to stay longer in the chain by recycling, which is a main characteristic of the circular economy. At the end of its life cycle, biomaterials still can be used to generate energy. As both biomaterials and biofuels rely on the same raw materials, appropriate political policies are required to create fair conditions for both sectors – a situation which is often called a "level playing field".

### 3.2.5.2 National policies

The main national frameworks for the biobased and the circular Economy are the following:

*Biomass Vision for 2030 (2015)[83]*

Focus is on valorisation of biomass and increasing supply of biomass especially residues. It considers the following measures:

- Enlarge the supply of sustainable biomass: improve collection of rest streams towards new commodities, enlarge the production of current biomass and on waste land and aquatic biomass.
- Optimization of utilization of crops and its components.
- New applications of biomass for biochemicals and biopolymers.
- Investment in new production capacity, in research and development and in new technologies: first of a kind fabrics, biorefineries, alternative protein production.
- Sustainability in the production chain and waste management.

*Circular Economy by 2050 (2016)[84]*

Biomass and Food is one of the five priority topics. Focus is on reducing primary raw material use and increasing use of residues and wastes, reducing imports and replacing fossil source with renewable sources. Three strategic goals are defined:

1. Optimising the use of biomass and food by closing loops;
2. Reducing the use of and replacing fossil resources by sustainably produced biomass;
3. Developing and implementing new production and consumption methods that lead to improvements and deviations from the trend in the use of biomass and food.

Optimum-level use of all elements of biomass and high-level reuse of (food) residues is emphasized. Furthermore, cascading use as a rule of thumb is advocated which concretely prioritizes material use of biomass before energy use since burning implies the raw material being lost.

*National Climate Agreement (2019)[85]*

The government foresees an indispensable role for biomass to achieve climate targets where cascading and high-quality use are seen as important points. Due to the increasing demand for

biomass as a renewable energy source and sustainable raw material, there is requirement to know whether there would be enough sustainable biomass available. The Netherlands Environmental Assessment Agency, PBL, expects bottlenecks in the supply in the period after 2030 in the Netherlands for all types of demand.[86] Until 2030 biomass can be used for multiple applications as a transition fuel. From 2030 it is important to use biomass primarily for high-value applications for which hardly any alternative, cost-effective sources are available, such as: heat for industry, biofuels for aviation and marine, and raw materials for chemicals and materials. The aim is to increase the supply of sustainable biomass as much as possible. The national government is aiming at doubling national production. An adequate food supply and preservation of soil fertility and quality of soil, water and air are important preconditions for the development of the biobased economy. In addition to increasing the sustainable supply of biomass, major challenges are the improvement of conversion techniques and market development to give biobased products preference over fossil based ones.

*Circular Agriculture*[87]
The Dutch Minister of Agriculture, Nature an Food is exploring the concept or Circular Farming. This is taking place at demonstration farms, within research programs and by bringing together experts at conferences. Ministry of LNV assesses possibilities to increase the biomass production in the Netherlands, based on potential of different landscape and soil characteristics looking at arable farming (e.g. sugar beets), lignocellulosic crops (e.g. Miscanthus), and wood.

#### 3.2.5.3 Province of Gelderland

*RIS3 Eastern Netherlands – Regional Innovation Strategy Smart Specialization*[88]
EU regions are challenged to make strategic choices to invest in specific sectors, which fits to the characteristics of their economies and environment, both physically and culturally, in comparison with other regions. Regions have chosen their profiles, strategies and plans, and organizational structures for implementation. Many regions have mentioned the bio-economy as one of the main drivers for regional innovation and growth. Within the bio-economy many routes are possible, depending on the combination of availability and components of the regional biomass and the existing industries for valorisation. The strengths of east Netherlands originate from the knowledge areas such as microbiology, sustainable and green chemistry, ecology, biobased materials & products and more specifically research into pyrolysis and other technologies, leading to new chains and techniques for a more sustainable economy. The province of Gelderland clearly focusses on three bioeconomy routes as drivers for regional innovation and growth: valorisation of manure, vegetable proteins and lignocellulose. Being the most wooded province of the country and hosting a significant paper industry, innovations in fibre applications of wood and fibre-rich crops and residues are a logical and very promising choice. This includes research into natural fibres, pilot industrial sites, biorefineries, stimulation of hemp and Miscanthus growing and residue/waste collection.

*Circular Economy Action Plan of Gelderland (2017)*[89]
The plan is aiming at supporting circular initiatives, pilots and awareness raising with the following tracks:
1. Province as a launching customer (circular buying strategy)
2. Smart and sustainable industry (paper, textile, construction). More efficient use of resources.
3. Valorisation of biomass and ingredients and components towards biobased products:
    a. vegetable protein
    b. natural fibres
    c. nutrients from manure

At the innovation track for natural fibres different new regional value chains between crops and industries have been explored, with much focus at the sustainable application in paper and textile industry. Kiemt Cluster foundation is supporting this development. The target is to process different fibre streams into high-quality natural fibre for sustainable applications in the industry.

*2019-2023 New political agreement 'Together for Gelderland'*[90]
The new provincial coalition will further invest in the circular economy, as part of the food and energy transition, with a focus on using waste as resources, limit imports of resources and use the current resources in the province as optimal as possible.

The province has ran a program on supporting new initiatives and pilot projects on the circular economy in Gelderland, fitting in the framework of the Circular Economy Action Plan. In the next phase of development, Gelderland wants to support initiatives which have the objective to scale-up, and has published a call for initiatives. Gelderland wants to have impact. Therefore collaboration in value chains and circular business models is important.

Circular Atlas (2019)[91]
The Circular Atlas focuses on:
- Decrease of use of primary or virgin resources and materials
- Reuse of resources and materials in closed circles
- Replace primary and finite resources by biomass and biobased resources

The province is searching for value chain projects in agrofood, construction, consumer waste and manufacturing industry. These sectors have the largest volumes of resource use, and they are challenged to come with project proposals, in order to realize a decrease in use of 50% of primary resources. Paper industry is part of the group of Manufacturing industries. One of the circular options considered is imported wood fibres, can be replaced by fibres from lower-value biobased raw materials. Options for this are fibres from residual flows from agriculture and horticulture or roadside grass.

Compared to the former framework on circular economy, Gelderland will focus more on value chains instead of individual business cases. This has contributed to the fact that in the new circular policy plan the focus will be on larger investment projects were two or more partners in the value chains work together. The challenge at the moment is to scale up (breakthrough) technologies and applications and realize market impact. Efforts must increasingly shift to the actual reduction of raw materials consumption, stimulating market demand, and realization. This is increasingly possible because economically profitable business cases emerge. This can be achieved by multiple valorisation of biomass (using all the fractions of biomass for different applications) and in this way formulate a solid business case. Policy objective regarding biomass availability and application in Gelderland: research how, where in Gelderland, what types, in which quantities and for which applications, extra biomass can be made available as raw material for new protein-rich food, regionally grown animal feed, construction material and the paper and textile industry. Draw up an implementation-focused, action plan together with (potential) producers of biomass, processors and market parties. Investigate whether a (provincial) incentive instrument can be created to open up the market for specific biomass applications to replace finite, fossil raw materials.

#### 3.2.5.4 Reflection on policies and strategic choices

Gelderland made a move towards biobased and circular economy. The start is no longer the existing biomass and agrofood production. Nor it is the comparative advantages with respect toother regions – which was central in the concept of RIS3. Policies on biobased valorisation seems to have less attention then some years ago and more focus toward circularity. Biobased innovations and specializations takes time and need long term support and strategic decision making. In the Circular Action Agenda and the Atlas, there is foremost attention to the volume of resources used by different sectors and industries. The objective is to decrease the use of resources (imports) and to optimally reuse waste. The valorisation of lignocellulose is still relevant for current industries, for the development of added value products in regional value chains, and for the deployment of the bioeconomy and also for the regional circular economy. There are few initiatives where conversion of rest materials from agrofood and collected fibre rich waste from other industries and consumers into new value added products is actually taking place, for example at Schut Papier. This is promising. To arrive at a certain scale and continuity, sourcing could be optimized, which may create opportunities for the agricultural and forestry sector to grow more fibre rich crops like Miscanthus and hemp. So the agrofood sector can play an important role in producing the biomass for regional paper industry, with a focus on niche applications. There is also a growing interest from textile industry and designers in using biomass and waste streams as a source for biobased materials and textile production. They can also play an important role in this circular economy of Gelderland, as part of the lignocellulose economy in Gelderland – to be taken into account as well when trying to come to recommendations.

In summary, what is needed for the regional valorisation of lignocellulosic biomass:

- Increase biomass availability
- invest in conversion technologies and facilities
- Build regional value chains and circular valorisation routes
- Multiple valorisation of biomass
- Discover and decide which products to produce in Gelderland
- Development to arrive from pilots to scale

### 3.2.5.5 Organization – Innovation Ecosystem

Regions build innovation ecosystems around their RIS3 priorities. They bring together different domains; knowledge institutes play an important role in the regional innovation, in interaction with public and private partners. There is also a growing focus on connecting with civil society; they are not aware of the perspectives of bioeconomy. Europe is investing in this connection. When civil society knows about the concept and the products, they will change behaviours.

Regions have their own characteristic biomass production and potential to valorise these resources, foremost using the biomass components in existing industries (sectors) towards new application with added value. New value chains between agriculture/forestry and other industries are being developed. It is important to connect the value chain partners. Very often the relation between primary producers and non-food industries is still lacking or difficult to connect.

Innovations often starts from fundamental knowledge and goes through different stages of ideation, exploration, testing and implementation, up to maturity. Therefore different support and facilities are needed. Regions invest in these infrastructure and facilities.

In Figure 7, the different stakeholders are grouped, along the value chain, different domains and the innovation facilities.


***Figure 7 Organization – Innovation Ecosystem for Local Lignocellulosic Fibres in the Local Paper and Board Industry***

An exercise was carried out to map all the different type of players existing that can enable new value-chains to be formed with local lignocellulosic biomass in the paper and board industry. Different players in the Netherlands are grouped into categories as:

1. Feedstock supply (potential suppliers of lignocellulosic biomass, such as Staatsbosbeheer for forestry biomass from forest management, Rijkswaterstaat for supply of grass from waterways

management, growers of Miscanthus, hemp and flax as well as farmers and greenhouses for agricultural residues and industry for industrial biomass residues)

2. Conversion technology to fibres (have the technology to convert the lignocellulosic feedstock to fibres, such as NewFoss and Grassa for grass and miscancell for Miscanthus)
4. Knowledge, test and production sites (Knowledge and testing institutes for testing, analysing and improving the performance of processes and quality of fibres such as WUR, Kennis Centrum Papier en Karton (KCPK), Probos, Kenniscentrum Plantenstoffen, stowa en BUNK). Also Radboud University and HAN university of Applied Science.
5. Market application (Paper and board industry who are the potential receivers of the fibres from local lignocellulosic biomass, such as Schut Papier, Huhtamaki and other paper and board producers)
6. Cluster organizations, Platforms (Kiemt, CIRCLES (Interreg project), Center of Expertise Biobased Economy)
7. Public services (Provide support through R&D investment such as the municipalities, national government and EU)

Although it is shown that many partners exist, at this point there is very little strategic collaboration between these. Partners are working on different levels of scale, some have focus on region, as others ate active in different parts of the Netherlands. Research programs are formulated at national level, and have nearly no regional focus or impact. The goal is to strengthen the communication and collaboration between these partners in order to develop local value chains. Currently few nice examples exist such as

- For the eggbox with grass fibres the collaboration between Staatsbosbeheer – NewFoss – WUR - Huhtamaki
- For the tomato boxes from tomato stems the collaboration between Lans Greenhouses – Van Vliet - WUR - Schut Papier – Solidus Solutions - the Greenery – Gemeente Westland – Kenniscentrum Plantenstoffen – Kenniscentrum Papier en Karton,
- For miscanthus book – BKC - ArtEZ hogeschool voor de Kunsten – Schut Papier

It is aimed to increase these nice examples and the volume of their application by increased collaboration.

It is also recommended to build new infrastructure for small-scale pulping (e.g. organsolv, or alkaline) to enhance the utilisation of wood and non-wood fibres by the local industries. This also calls for setting up logistic centres for biomass storage (see Betuwse bloem project).

## 3.3 Changes in the Key Sector

In order to illustrate changes in the key sector of paper industry an application example is chosen: GreeNest, egg box made with grass fibres. This business case is about production low quality board with sustainability benefits (see section 3.2.3, Figure 4 low value, niche market). The key is low prices, right and consistent quality and added value due to sustainability, circularity and local biomass use.

In order to address the growing trend of organic and free-range eggs, Huhtamaki commercialized a completely new moulded fibre packaging with 50% grass fibre content (GreeNest).[52] This was done in collaboration with Staatsbosbeheer[92] who supplies the grass from nature reserves and NewFoss who produces fibres from grass (see Figure 8). Natural grass often consists of a hundred different plant species and is therefore not suitable as animal feed. Huhtamaki treats the grass fibres into pulp and by mixing these fibres with old paper fibres, a strong and durable product is created: grass cardboard.

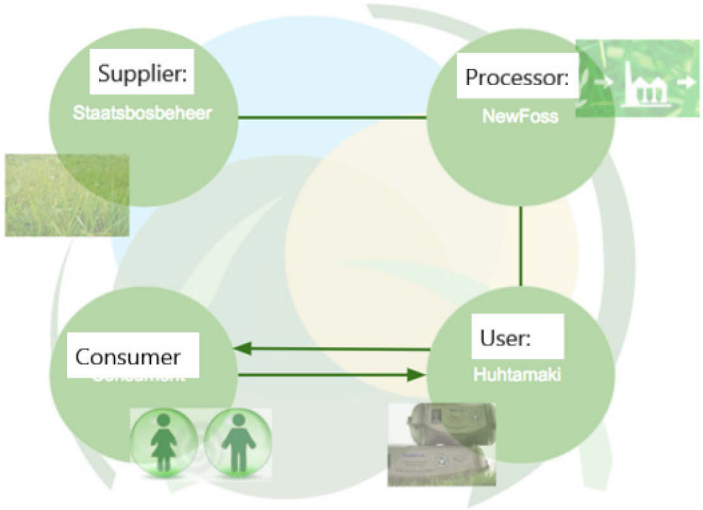


***Figure 8 Stakeholders involved in the chain of GreeNest egg boxes***

The egg boxes (GreeNest) are made of 50% grass fibres and 50% recycled paper fibres by weight. A kilo of natural grass yields 20 egg boxes.[52] Boxes made from grass fibres can provide direct replacement of the conventional boxes in terms of functionality. After use, the egg box can simply be recycled with the old paper for reuse. This enables valorisation of Dutch grass in the Dutch paper industry. The estimated potential grass in the Netherlands is 2.9 million tonnes per year wet basis but currently less than 10.000 tonnes is used per year for the production of egg boxes.[93] The market increasingly demands sustainable packaging. It is indicated that 1 in 5 consumers worldwide have Huhtamaki packaging in their hands (this includes all their packaging products).[52] In the process as a side product grass juice is produced which is rich in organic products. It can be digested in an anaerobic digester to biogas which provides more than enough to meet the energy demand of the fibre production process. The excess energy can be used in the packaging production process. It is estimated that this can result in 7% reduction of the natural gas use.[94] Through personal communication it is learned that Huhtamaki no longer receives grass fibres from NewFoss but they installed a grass refining unit in their facility where they produce the fibres themselves.

In this study, it is considered that 5,000 tonnes of grass per year is used in producing egg boxes. With the knowledge that 1 box weighs 27 g and 1 kg grass results in 20 egg boxes, it can be calculated that 2700 tonnes of egg boxes can be produced per year with feedstock composed of 50% grass and 50% recycled paper (see Figure 9).

The grass fibres are produced from nature grass by a biological process close to ensilage that opens the plant cells and releases the cell liquid. The remaining fibres are used for the production of egg boxes, without a chemical pulping process. The liquid called the grass juice can be anaerobically digested to produce biogas which can supply the energy demand of refining of grass and part of the carton making process. This possibility is currently not applied but would enable significant saving in terms of natural gas consumption. It can be estimated that this will lead to 100.000 $m^3$ biogas per year production.[94]

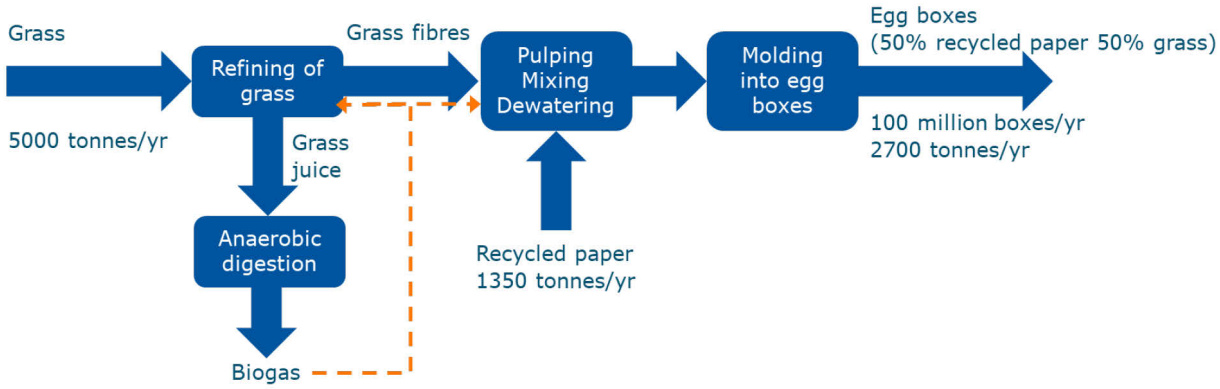


***Figure 9 Process scheme for the production of GreeNest egg boxes***

Changes in the sector with the basis of conventional egg box production is the replacement of 1350 tonnes of recycled paper by grass fibres (dry basis) per 100 million boxes per year. The replacement with grass fibres doesn't result in any change in the functionality of the boxes. They offer the same protection properties and they can be recycled together with old paper. The refining of the grass process is an additional step compared to the production process for the conventional egg box production. There is a requirement of transportation of the grass and processing to separate the grass fibres. Due to the water content of the grass the transportation demand is higher compared to transportation of wood pulp or recycled paper. However the refining of the grass can be beneficial in term of producing biogas from the side stream grass juice. Also the process doesn't require any chemical additives and occurs by a natural process. Furthermore, the producers explain that the replacement of 50% with grass fibres allow 50% reduction in water consumption.[92]

## 3.4 Economic, Environmental, Social and Circularity Assessment of the New Business Case

Following the example described in section 3.3, economic, environmental, social and circularity assessment of the new business case is presented below.

### 3.4.1 Economic

Nature grass and roadside grass, in principle, are cheaper than recycle paper as these types of grasses are currently composted, which costs money. Owners of harvested grass will be motivated to bring the grass to the egg-box manufacturer, if this new application costs less money or if it results in a profit. However, before the grass ends up in an egg box, transport costs and pretreatment (refining) costs are involved.
Currently the prices of grass-based egg-boxes are higher than the conventional grey egg-boxes.

- Conventional grey six-egg-boxes in a quantity of 228 pieces cost € 0.19 per box including VAT on the wholesale market. Since the weight of a six-egg-box is 27 g, the price per tonne amounts € 7037 including VAT.[95]
- The six-egg-boxes made from 50% grass and 50% recycle paper are sold for € 0.25 per box including VAT, when purchased in quantities of also 228 boxes. That would mean € 9259/tonne including VAT.[96]

This means that grass-based egg-boxes are more expensive. The higher price can be explained by the additional processing costs required to separate the grass fibres. The higher price is accepted as it provides additional value for a specific category of customers owing to sustainability and circularity benefits and green image.

Another economic motivation for egg-box producers to use grass is diversification of the raw material. Recycle paper prices and availability now depend on developments in the markets. One example is the changing need for European recycle paper by China and another is dealing with digital revolution less paper used and by ordering online more corrugated board is used. Furthermore, in the future, demand for fibres may increase, both nationally and internationally, due to the transition towards a biobased economy. Therefore, a shift towards more domestic resources as an alternative feedstock such as readily available grass may reduce the risks.

### 3.4.2 Environmental

Grass, has a short growth cycle. Mowed grass can be collected about three to four times a year. If the grass fibres allow replacement of imported cellulose from virgin wood, it allows reducing demand on forests, which is important for several environmental aspects including biodiversity preservation and climate impact from deforestation.

Converting grass into material allows the $CO_2$ absorbed to be stored which would otherwise be emitted back to atmosphere. By material application the $CO_2$ absorbed can stay longer in the cycle by recycling. It is claimed to be possible to recycle the eggbox made with grass fibres in the same way and as many times as done with the recycled paper made boxes.

Huhtamaki reports that by replacing half of the recycled paper with grass fibres for the eggboxes, carbon footprint of the product has decreased by 10% and the water consumption decreased by 50%.[52] Furthermore, by anaerobically digesting the grass juice side stream biogas can be produced. It can supply part of the energy demand of the production process and would allow additional $CO_2$ reduction to be achieved by substitution of natural gas.

### 3.4.3 Social

In the Circular Atlas Gelderland (2019)[91] the total jobs in paper related industry (46 companies) in Gelderland is estimated on 3400. If the paper industry increases the amounts of local feedstocks used, jobs will be created to collect or produce these amounts, and additionally to pre-process to separate the fibres. In addition, it will increase the social cohesion in the Gelderland community because of the interdependency established. The regional development will comprise the creation of new structures in harvesting, production, logistics and inter-human relationships. It is expected that paper products that are sustainable and produced locally from local feedstocks get more sympathy of the customer, who will be willing to pay more for the products. Furthermore the sustainability and circularity benefits created are appealing to certain customers.

### 3.4.4 Circularity

The essence of a circular economy is that products and materials keep circulating while retaining the value of the resources incorporated in it, for as long as possible. Thereby several aspects need to be considered to assess the circularity performance of grass-fibre based eggboxes:

1. Functionality

Functionality refers to what extend the original structure of the biomass is conserved when producing the product out of biomass. It is better to use the functional qualities first, as the components (such as fibres) will usually be preserved in the product and may be used again later. By valorising the fibres present in the grass for a material application, the functionality is retained. If it would be composted or burned on field it would be broken down and there will be significant loss in functionality in one step.

2. Retaining functionality

The second consideration is about what happens to the bio-based products after use. It concerns the quality of the recycled/secondary material and how it can be used afterwards. The grass eggboxes can be recycled and the recycled product can fulfil the same function as in the first cycle (closed-loop recycling - recycled paper to new paper). They can be recycled together with old paper and don't have difference in quality with the conventional recycled paper. Paper can be recycled several times and at the end of life can be burned to recover energy.

3. Resource use efficiency

Grass can be cut about three to four times a year so provide high land use efficiency. They grow in pastures and also can be recovered from nature and waterways management. Grasses are locally available and underutilised resources so valorising them for materials allow high resource use efficiency. The fibre component is used for making the eggboxes. The residual grass juice can be also utilized – anaerobically digested to produce biogas which will increase the resource use efficiency. Furthermore, it is indicated that the water used in process can be cleaned and recycled completely.

4. Recycling efficiency

It is indicated that the grass-fibre based products can be recycled together with old paper. It is not expected that the recycling efficiency will be negatively influenced with the presence of alternative lignocellulosic fibres but this needs still to be confirmed.

## 3.5 Expected Effects on Other Sectors and Alternative Uses of Biomass

*Expected Effect on Other Sectors:*

*Energy sector*
There is competition concerning the use of biomass for energy and material use. By having an additional outlet for the feedstock can result in an increase in the price and problem with availability.

*Transport sector*
With the decrease in dependence of imports, international transportation demand is expected to decrease. Due to need for increased mobilisation of resources internally, transportation demand within the country is expected to increase.

*Paper recycling sector*
Presence of paper and board made with other sources of fibres can require adaptations to be made in the recycling process.

*Agriculture*
Diversion of the agricultural residues from land to material application can have negative effect on the soil quality if sustainable harvesting levels are exceeded.

*Forestry*
Where harvest of logs is generally profitable, harvest of branch wood from forest is still expensive compared to the benefits.[76] Besides, it can have negative effects on soil fertility.[73] De Jong et al. (2012) however show that harvest of wood may also create positive effects on biodiversity, such as improved habitats and circumstances for species depending on open spaces and gradients in forests.[32] Harvest in appointed nature forest may be done at low levels removing e.g. exotic species and creating gaps. Increased harvest in forest should be planned well, considering soil type and fertility, and situating open spaces and regeneration areas is such a way if provides benefits for biodiversity.

*Nature, landscape and urban green management*
Composting of biomass from common nature, landscape and urban green is costly. Reduction of costs of disposing of grass, or even create a use, will have a strong effect on the economics. It may make road managers use different management methods. Flail mowing, leaving the grass on site, is still common practise at roadsides but may be replaced more often by methods of removing of the grass, e.g. with disc mowers. In this way excess of nutrients are removed from roadsides, leading to richer plant communities and improved circumstances for insects. To achieve good quality clippings, the cooperation of the site managers is needed to apply special mowing policy (how often and when in the season to mow) and machines.[92]

*Alternative Uses of Biomass:*
Lignocellulosic biomass can have alternative uses than the use for paper/board:

- Leave on land (forest, agriculture)
- Compost
- Produce energy by combustion
- Anaerobic digestion to produce biogas and digestate
- Use of lignocellulosic fibres in other material applications such as for textile and construction
- Processing to produce sugars than can be used to produce transportation fuels or chemicals

## 3.6 Frameworks, Governance and Policy to Create Enabling Factors and Solve Barriers

Support the development of a Gelderland fibre economy by producing and collecting lignocellulosic biomass optimally in Gelderland, by processing and converting into specialty products by local paper and other fibres valorisation industries (textiles, construction).

The advantages/opportunities are for Gelderland:

- Increased biomass production will also allow capturing more $CO_2$
- Contribution to circular economy by valorisation of residues and underutilised resources
- Contribution to circular farming
- Less dependence on import of resources
- Optimal use of comparative advantages of existing industries, knowledge and capacities
- Potential for new value added applications and activities

The Province of Gelderland and their partners should optimally cooperate together in creating an innovation ecosystem and support services for these developments. Optimally supporting the innovation process, initiatives from ideation, exploration, demonstration and into implementation through knowledge programs and financial support. The value chain partners need to be brought together to explore potential value chain development. Further the technological equipment and facilities should be taken into account in order to take the right decisions for investment in Gelderland conversion facility.

The province of Gelderland has distinguished the following roles, tools and instruments to enable the development towards a circular economy:

- Collect best circular practices and give leading entrepreneurs and frontrunners the 'stage' to inform, inspire and encourage others to follow their example (communication).
- Set up and adjust (provincial) financial instruments.
- Promote triple helix collaboration around clusters, value chains and prime locations.
- Support business and product development.
- Take a leading role as launching costumer in purchasing and tendering.
- Include circular economy in provincial programmes and instruments: economy and innovation, energy transition, sports, building environment and spatial planning, labour market development, mobility and infrastructure, soil/water/biodiversity, nature management.
- Insist on and lobby for supra-provincial issues, for instance: stimulating laws and regulations, emission trading, $CO_2$ pricing, tax reduction, % circular materials (waste/residues) and % biomass in new products etc.

Next to these instruments of public sector, also the knowledge domain can support the circular economy by bringing research into practice. Connection of research base of WUR and other knowledge partners in the province, with the policies and the private sector initiatives needs to be supported. This requires investments in research and innovation from provincial government, focusing on their RIS3 strategic topics and innovative value chains. This also requires opening up the research base of knowledge institutes, making the knowledge operational by bringing the knowledge further in the knowledge value chain. Willingness to bring the fundamental and applied research further into innovations in the regional context and strategic partnership between province and knowledge institutes are needed. Also knowledge brokers to connect policies, private sector and knowledge institutes can play a supportive role. This can be done by making capacities available for those positions, or by investing in in-between organizations as cluster organizations or other intermediates. Also the private sector can enhance the enabling factors. For the use of lignocellulosic biomass, the KCPK and the KIEMT cluster can fulfil these needs. Province and knowledge institutes should invest more in setting up newly or connect existing knowledge programs to the regional innovation agenda, and invest in valorisation of knowledge.

# 4 Conclusions

This project provides a knowledge base to contribute to the regional development of new biobased value chains in Gelderland. A stepwise case study methodology was applied, which considers also inclusion of a circularity assessment. With the case study, the impact of the new business case on the transition path towards a circular and biobased economy was assessed. It gives insight in the different aspects of the business case: technology, environment, economic, society and circularity. Information regarding the baseline is provided which gives insights into the availability of lignocellulosic biomass in the region, the current status of the paper industry in Gelderland and current supply of biomass to the industry. It was seen that local availability of data is problematic (who is producing, how much is produced, how much more can be available), this information is not readily available or reported. With the new business case the use of local fibre-rich biomass for paper and board is considered in order to create new value. This allows to create value from underutilized resources, keep the carbon stored in a product and by possibility of recycling several times it can stay longer in the cycle. This is supportive of reaching targets to combat climate change and contributes to circular economy. It is seen that currently there is much reliance on imports (pulp from virgin wood) due to economies of scale. To rely more on domestic resources instead of imported ones, means less dependence on highly volatile demand for pulp and recycled paper. Large companies are hesitant to make this transition. However, several new initiatives are available exploring new innovative value chains.

The required conversion technologies and new initiatives in this regard is explained. To show the potential, the current nice application examples of local lignocellulosic biomass is provided. One example, the eggboxes using grass fibre, was selected as an example to show how the process looks like and its impacts in terms of economics, environment, society and circularity. A novel aspect of this assessment is the evaluation in terms of circularity indicators proposed for biobased products: functionality, retaining functionality, resource use efficiency and recycling efficiency. By valorising the fibres present in the grass for a material application, the functionality is retained as the fibre component of the biomass is preserved. After use the functionality is retained as they can fulfil the same function (paper/board) as in the first cycle by recycling. Due to quick growth and possibility to collect several times a year, grass provides a high land use efficiency. Looking at processing, utilising the residual grass juice after separation of fibres for biogas production would allow a high resource use efficiency. Considering the recycling efficiency, it should be considered that the presence of alternative lignocellulosic fibres shouldn't have an adverse effect on the recycling process. Considering the social dimension, new jobs will be created for production, harvesting/collection, logistics, pre-processing of local lignocellulosic feedstocks. Converting grass into material allows the $CO_2$ to be stored which would otherwise be emitted back to atmosphere. This is important consideration for climate change. In terms of economics, the price of grass-based egg-boxes are higher than the standard egg-boxes. But customers are willing to pay a green premium for the associated sustainability and circularity benefits.

Due to the strong paper industry of Gelderland, there is potential that the national lignocellulosic resources can be valorised here as a lignocellulose hub. An overview of the policies at European, national and provincial level is provided which show that the frameworks are there, and the challenge now is to bring the missions into practice, to realize the bio-economy, create new perspectives for regional economies in balance with the planetary boundaries.

# Acknowledgements

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