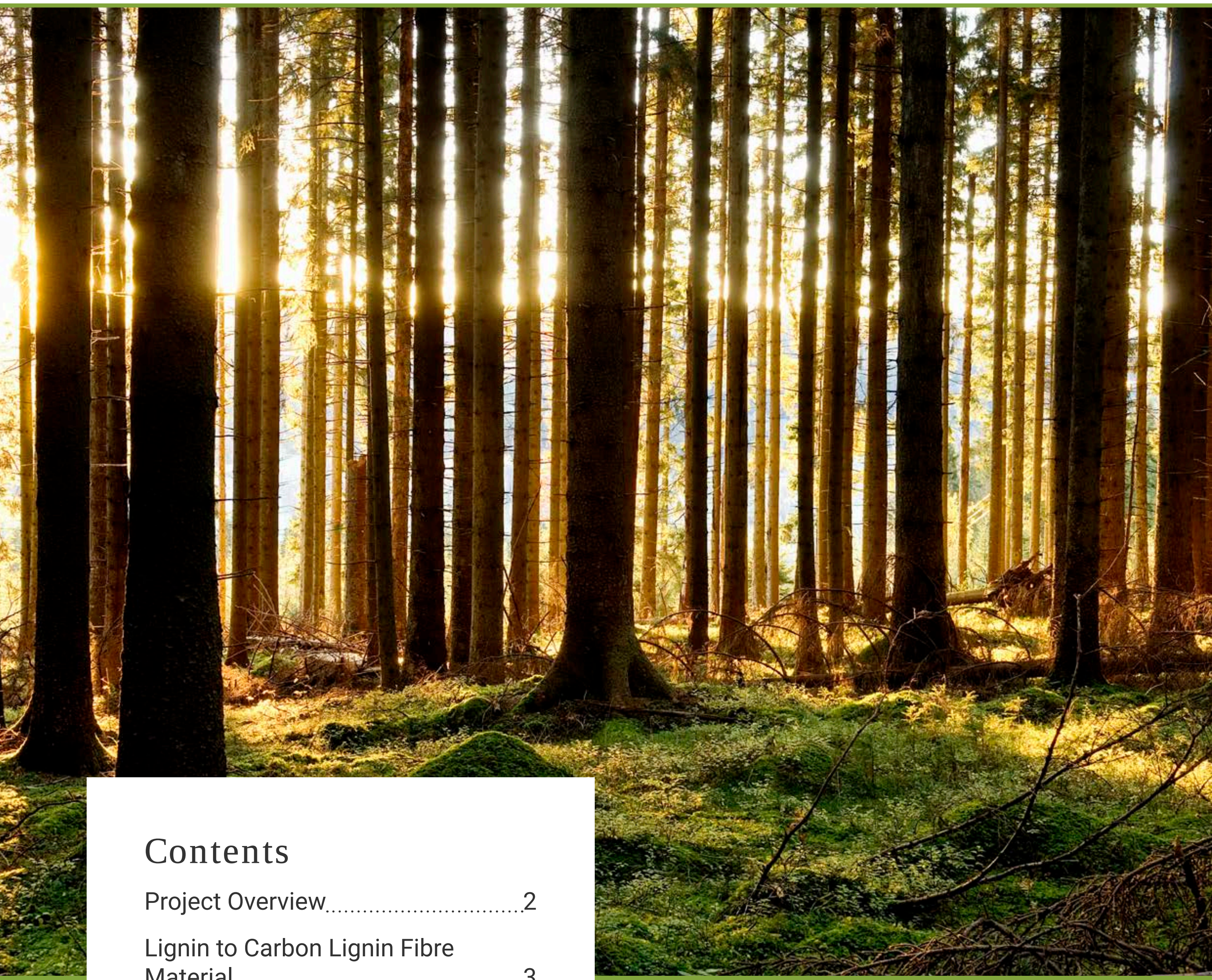
GreenLight



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Project Overview

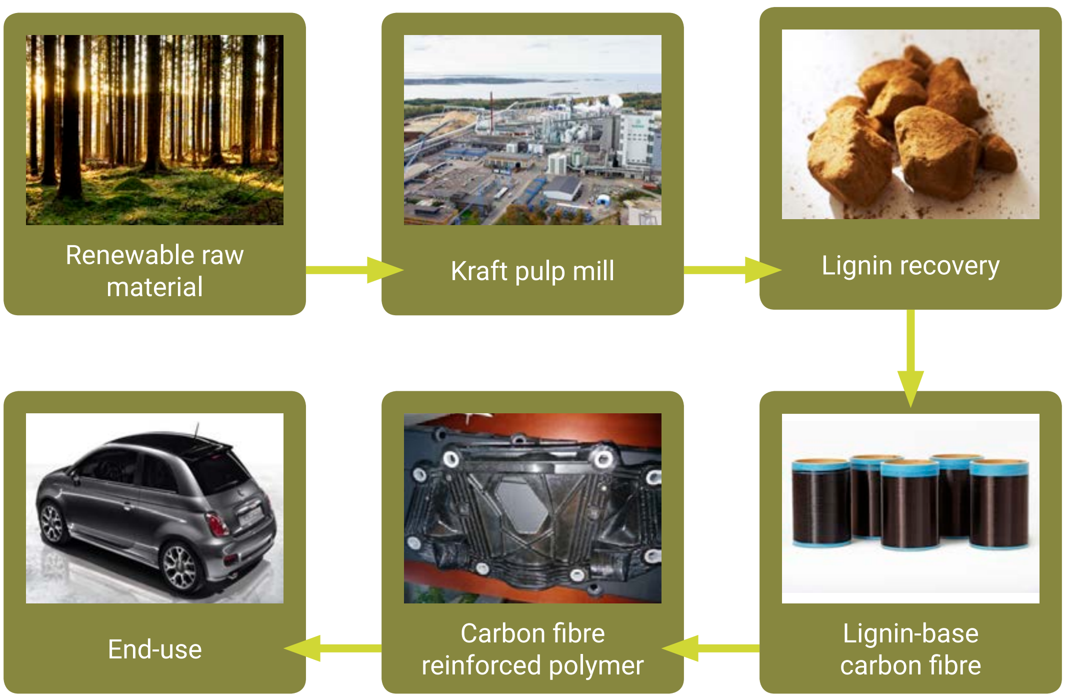
GreenLight is a collaborative project part-funded by the European Commission. It has 9 partners from four European countries and a total budget of over €2.6 MILLION. The project started on 1 July 2015 and will finish on 30 June 2019.

The aim of GreenLight project is to demonstrate a new biobased, renewable and economically viable carbon fibre (CF) precursor – lignin – produced in Europe with European raw material and to develop conditions for its processing into CF and structural CF composites.

CF reinforced plastics has been introduced as a low-weight material replacing/complementing steel and aluminium. Today's CF production is based on use of a petroleum-based raw material, PAN, which is costly due to the starting precursor and the process for turning it into CF. Most PAN used in Europe is imported. The automotive sector has identified a need for a cheaper lower-grade CF to meet the demands of components in normal consumer cars. Lignin from kraft pulp mills is a green, sustainable, abundant and cost-efficient new potential CF precursor.

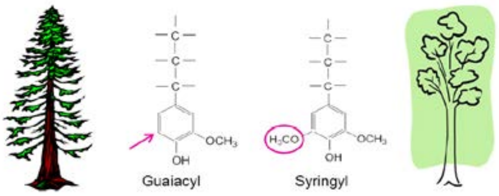
The development of lignin-based CF is still in laboratory scale and material properties meeting high-quality product demands is the main challenge. The LignoBoost technology that has recently been introduced in commercial operation makes it possible to produce lignin with new properties, higher purity and with less impact on the pulp mill operation. The idea is to tailor kraft lignin properties already in the lignin separation/upgrading and optimise the lignin for target automotive applications.

GreenLight has demonstrated the continuous multifilament spinning of 100% softwood lignin into high quality filaments. Based on the promising mechanical performances, lignin-based carbon fibres could have a potential large-volume automotive application in manufacturing short fibre composites which have lower production cost and broad applications. With a competitive price, lower than the conventional PAN-based carbon fibre, a preliminary life-cycle assessment shows a lower global warming potential for the GreenLight carbon fibre than for glass fibre.



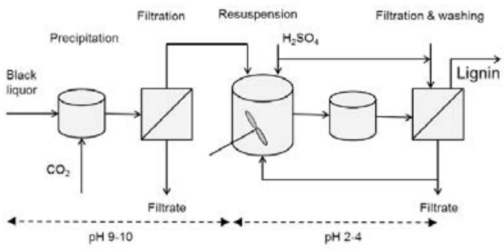
Lignin to Carbon Lignin Fibre Material

Lignin is present in all fibrous plants, it is a bio-based renewable material, with a carbon content of 61-69%, similar to that of PAN (65%). It is a macromolecule consisting of phenylpropane units with a structure depending on its origin. For example, softwood lignin is mainly composed of guaiacyl units, while hardwood lignin mainly consists of syringyl and guaiacyl units.



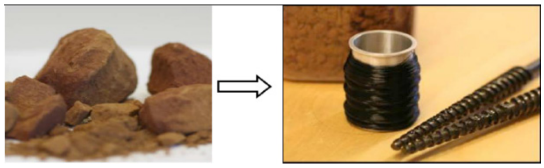
The largest industrial source of lignin is the kraft pulp and paper industry which handles large amounts of lignin within its operations already today: 40 million tonnes of kraft lignin handled by the kraft pulp mills. Most paper products require lignin to be removed from the wood pulp. During the kraft pulping process, the major part of lignin in wood is dissolved into the processing liquor, which is called black liquor.

RISE and Chalmers University of Technology (Sweden) have developed an efficient commercial technique, called the LignoBoost, which allows to produce a high purity lignin from the black liquor streams.

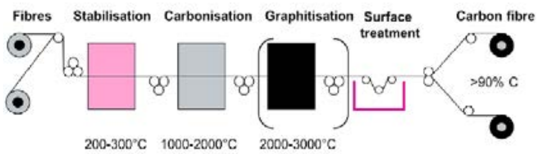


In brief, carbon dioxide is added to the black liquor which causes kraft lignin to be precipitated. The lignin is then filtered, resuspended in sulphuric acid, filtered again and washed to obtain a fuel purity grade lignin. The advantage compared to previous technologies is that the lignin have a low carbohydrate content (<3%) and very low ash content (0.5-1%).

The GreenLight approach was to modify and further develop kraft lignin, based on the LignoBoost process, with a new concept optimised for turning lignin into a carbon fibre precursor. Here, lignin has been spun into precursor yarns with up to 250 filaments fibre by melt spinning of softwood kraft lignin. Through a new developed spinning process precursor yarns up to 1000 filaments can be realised. Melt spinning is achieved by heating to above the melting/softening temperature of the raw material, and is facilitated by mechanical shearing by the extrusion screws.



The following step is to produce the lignin-CF from precursor fibres in a continuous process. During the stabilisation, the precursor fibre is heated in an oxidative atmosphere to prevent melting of the filaments during carbonisation. Then the fibres are carbonised in inert atmosphere at high temperatures: a weight loss of around 40-50% takes place and the carbon content is increased to 95-98% due to the fibre diameter shrinking. Finally, the CF is oxidised to remove weak surface layers and the surface is commonly sized to protect and facilitate handling.



Sustainable Composite Carbon Lignin Fibre Processing

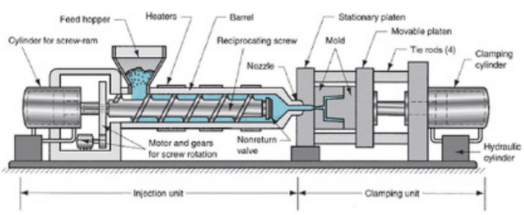
One of the objectives was to define and present the most promising processing options for converting the lignin-based carbon fibres, which are non-continuous, into finished moulded components. Therefore, composite moulding processes with non-continuous fibre forms are elevated as the most promising composite processing methods for industrial scale up: injection moulding and SMC processes have been respectively selected for thermoplastic and thermosetting matrix composite processing.

Injection Moulding

Process used to produce short fibre reinforced polymer composites (SFRP). With a mechanical properties competitive with glass fibre and natural fibres, lignin-based CF used as advanced short fibre reinforcing material is highly attractive for many applications in the automotive industry because of

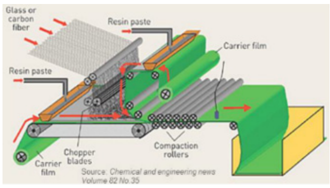
- Mass production at low cost
- Lightweight materials,
- Mechanical performances,
- Recyclability, repeatability, and corrosion resistance,
- Shaping complex geometries.

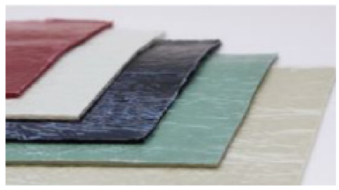
The short fibres are mixed with a thermoplastic material into a pellet form, which are melted, and a product is formed thru injection moulding. The blending of raw materials is processed into a pellet form thru compounding or pultrusion. Thermoplastic material is heated until it becomes a viscous melt and then dosed by force into a closed mould that defines the shape of the article to be produced. The material is then cooled in the mould until it solidifies, and the part can be extracted from the mould.



Sheet Moulding Compound

SMC is defined by a thermosetting resin matrix, reinforcement and inorganic filler. The SMS machine principle consists of: a plastic film on top and bottom side are coated with the matrix blend and dispersed with a doctor blade for correct matrix proportion in relation to the fibre. The fibres are chopped in between the coated plastic films and compaction rollers homogenize the matrix and the fibres to a compound as a continuous sheet.





Composite parts are manufactured by placing the SMC in a heated mould and apply pressure to let the material flow into the all parts of the mould: self-sealing flow process where SMC charge is be compressed, heated and start to flow out towards the "shear edge" where it seals off the mould and start to pressurize the material. A key feature of manufacturing composite parts with SMC that makes it particularly useful for the automotive industry:

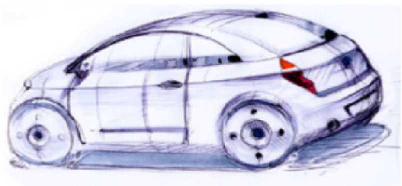
- Easy processing,
- Ability to form complex shapes
- Short cycle time
- High volume manufacturing.

Case Studies

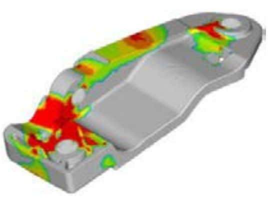
Two different case study components were defined to show the potential use of the lignin-CF. Several steps performed for the evaluation: virtual analysis of compounds, transfer of virtual data on real components and demonstrator manufacturing. Fibres has been tested at virtual and experimental level to show the possibility to follow two strategies of weight reduction for automotive sector: metal replacement (composites instead of steel) and plastic replacement (carbon fibres instead of glass fibres).

Seatbelt bracket: thermoplastic case study

The component considered is a CF reinforced thermoplastic seatbelt bracket produced by injection moulding and is related to metal replacement.

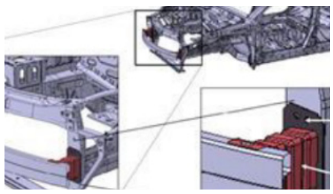


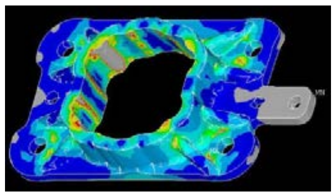
The virtual analysis of the bracket design was conducted using chopped lignin CF and E-glass fibres. The results of virtual modelling of the materials showed a 10% increase of performance using lignin CF in respect to E-glass using current achieved fibre properties at lab level. Development of processes conditions to produce lignin CFs is however expected to improve the fibre properties. With these estimated properties the improved final properties of compound are close to 40% compared to E-glass. Finally, the development and production of thermoplastic components in pre-series using a benchmarking material with the same modelled properties showed process compatibility and a final weight reduction >30%.



Crash-box: thermoset case study

The chosen thermo-set demonstrator manufactured is an automotive detail in sheet moulding compound (SMC). It is a back-plate to a so-called crash-box with the main function to be a holder for the crash-box and connect the crash-box to the body of the car, while the role of the crash-box is to absorb a lot of energy in case of a car-crash..



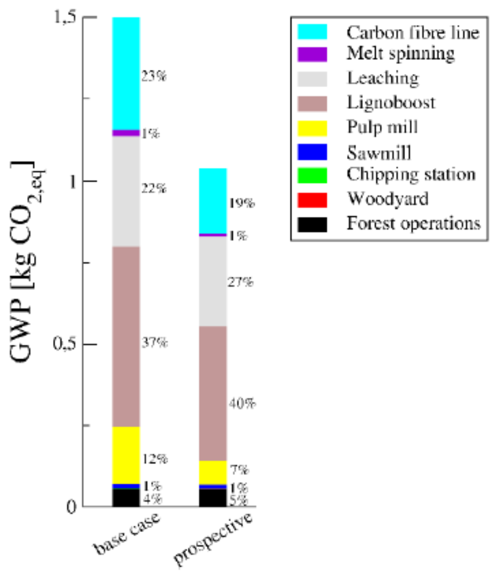


Based on the lignin-CF properties, the Finite Element analysis showed some very promising performances compared to a standard “Toray-SMC”, mainly in tension load where the FE model will survey the load even if the calculated stress at some smaller areas very locally exceeds ultimate stress. However some improvements are required to fully answer to the mechanical properties, especially in compression load where the performance can be improve by optimizing the geometry or using longer fibres locally.

Final Life Cycle Assessment (LCA) & Techno-economical concept

The LCA study aims at determining the environmental impact of the GreenLight production process and intends to help guide further development of the process. The LCA was done from cradle to gate and followed an attributional approach.

The climate impact per kg of L-CF produced is 1.50 kg CO2,eq. The main contributor to this impact is the production and use of chemicals in the different process steps. The climate impact of the L-CF production is significantly reduced compared to the glass fibre production and the polyacrylonitrile-based carbon fibre (PAN-CF) production: by 30% and approximately 10 times, respectively.



Sensitivity analysis showed that changes in market pulp and lignin prices lead to the greatest changes in the environmental impact. A prospective analysis, in which the background energy system is cleaner, showed that the impacts of the GreenLight production system will decrease and outperform the glass fibre and PAN-CF production from a climate point-of-view.

Socio-economic aspect	Comments	
Employment and economic impact	The carbon fiber plant is labor-intensive Generate new jobs (plant builded)	Positive Effect
Stakeholder participation	Effective use of resource in the plant and the Project positively impact the society	
Increased export	The major part of the 1500 ton/year will probably be exported.	
Conflicts regarding land and water use	Land already industrial ➔ no conflict (no important additional water used)	
Road traffic	Limited effects from the new plant.	Neutral Effect

The techno-economic evaluation shows that the price of a lignin-based carbon fibre could be at or even below the minimum price range (9-12 EUR/kg CF) that is required for mass deployment in the automotive industry. However, the development of the lignin-based carbon fibre in Greenlight is in an early stage and it did not reach the DOE's mechanical properties fully. Instead the Greenlight carbon fibre properties is closer to glass fibre. Glass fibres are however cheaper than carbon fibres, but carbon fibres are lighter than glass fibres, so less material is needed and the lower fuel consumption resulting from this could still be in favour for this early-stage developed lignin carbon fibre.

Main Achievements

Properties & Performance

- Continuous multifilament spinning (about 100 filaments) of 100% softwood lignin into high quality and low diameter filaments.
- The tensile properties of fibres are the highest reported for melt-spun pure lignin-based carbon fibres.
- The conversion process can be done at a relatively fast speed compared to what has been reported for lignin-based carbon fibres.
- Lignin-based carbon fibres could have a potential application in manufacturing short fibre composites (injection moulding & SMC processes) which have lower production cost and broad applications.
- A new spinning process for lignin has been developed, which allows continuous spinning and winding with automatic spool change. Application for a patent is in progress.

Price / Environment impact

- Cheap: could be at or even below the minimum price range (9-12 EUR/kg CF) that is required for mass deployment in the automotive industry.
- Potential lower price than the conventional PAN-based carbon fibre.
- 1.50 kg $CO_{2,eq}$
- Climate impact: reduce by 30% compared to the production of glass fibre
- New market segments could be opened for the carbon fibre industry and, thereby, for the pulp industry.

GreenLight

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