# Prospective Life Cycle Assessment of Recycled Carbon Fibres from a Solvolysis Process and their Potential Applications in the Transport and Building Sector

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Due to the high energy demand and consumption of non-renewable resources for the production of today's virgin carbon fibres (vCF) based on Polyacrylonitrile (PAN), their multiple use in a potential circular economy is desirable. The EDISON-rCF project demonstrates the potentials of a recycling process chain for carbon fibre reinforced polymers (CFRP). One- and two-dimensional semi-finished products for subsequential use in the transport and building sector are developed and tested based on recycled carbon fibres (rCF) obtained from an improved Solvolysis process. The study includes a prospective LCA of a potential rCF reinforced concrete (rCC), showing promising results together with high uncertainty due to lab data from different technology maturity levels as well as gaps in background data. Here, some cradle-to-gate results for rCC are discussed.

**Fig. 1: rCF-Rebar®, the world's first concrete rebar out of rCF from Zeisberg Carbon (photo: Stefan Gröschel, TU Dresden)**

## Carbon Fibre Reinforced Concrete

Carbon fibre (CF) reinforcements offer an exceptional corrosion resistance compared to steel, hence the concrete cover can be reduced to a minimum. This opens up new design opportunities due to the previously impossible thinness of such concrete.

From environmental point of view, the reduction of concrete and its inevitable embodied $CO_2$ emissions - mainly from the clinker production - is beneficial. However, the production of vCF is energy intensive and may overcompensate these positive effects. While LCA results for vCF show high uncertainty due to lack of public available primary data and a large range of literature data [1], a utilization of rCF in reinforced concrete is a promising alternative.

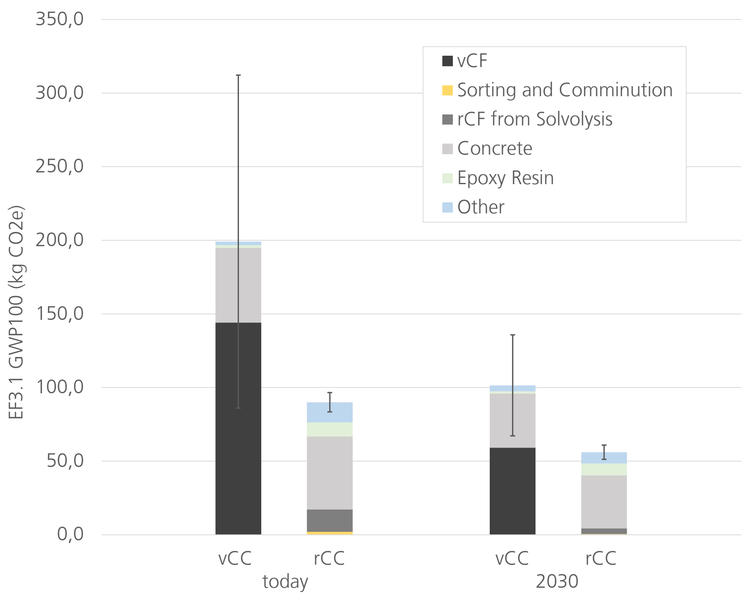


**Fig. 3: Cradle-to-Gate GWP** of carbon concrete reinforced with vCF (vCC) and rCF (rCC). The functional unit* is based on the calculation of a similar mechanical performance according to the guideline for concrete structures with nonmentallic reinforcement of the German Comittee for Reinforced Concrete (DAfStb). 'Other' includes nonwoven, yarn and rebar production steps.**

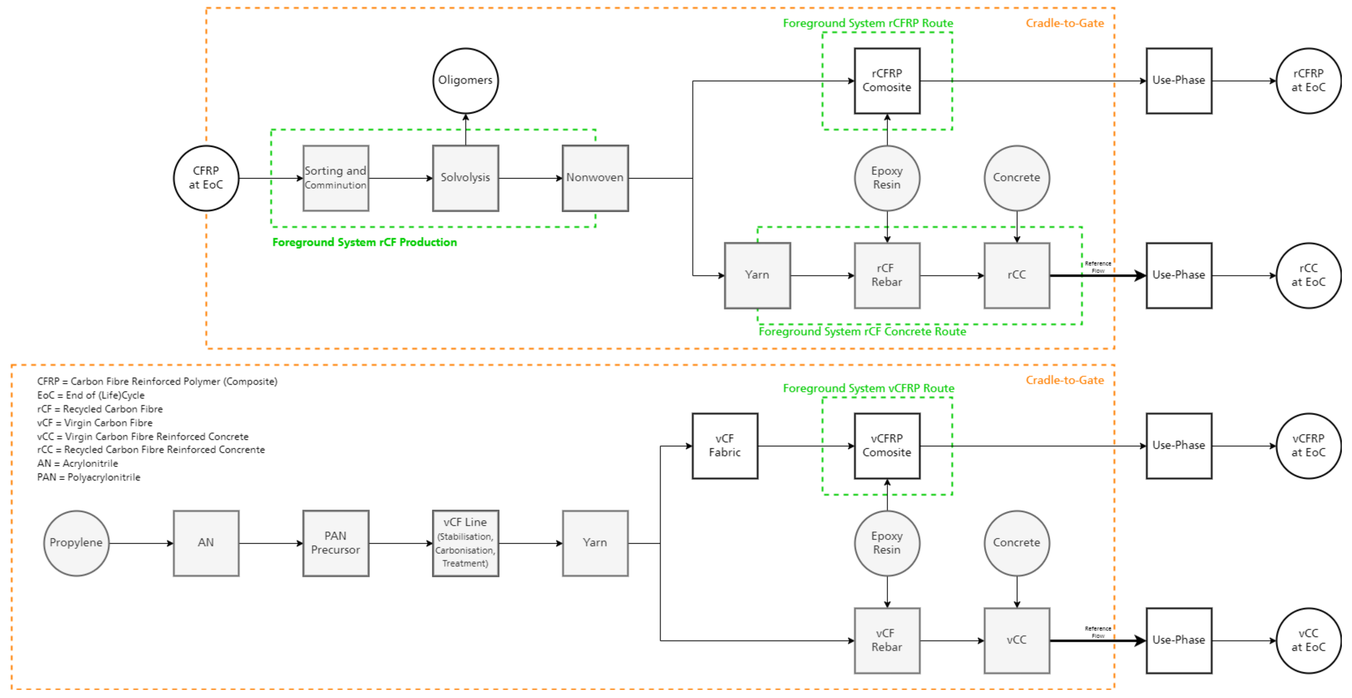


**Fig. 2: Main process steps, foreground data (green) and system boundaries (blue) of the LCA study* in the EDISON project. Here, only the carbon concrete route for rCF (upper flowchart) and vCF (lower flowchart) is presented in more detail, indicated by the grey filled process steps respectively used materials.**

As demonstrated in the project, solvolysed rCF can be produced with a GWP between 2 and 4 kg $CO_2$e/kg, depending on size of reactor, type of solvents and their internal recycling efficiency. This puts the Solvolysis potentially in a lower range as the already industrialised Pyrolysis [2]. Additional benefits from the potential utilisation of oligomers are not yet considered in this study. However, recycling leads to a reduction in fibre properties (downcycling) that requires a different processing in order to prepare them for new applications, resulting in more rCF necessary compared to vCF to obtain similar mechanical properties in a carbon concrete.

## Two scenarios: Today and 2030

In addition to the model for today, a prospective LCA scenario was modelled for the year 2030 in Germany*. However, the limited availability of suitable data sets for future scenarios and limitations to remodel the datasets in the used commercial software reduce the significance of the results beyond the main foreground processes. Further work is necessary to improve the significance of the study by adding steel reinforced concrete into the comparison. Additionally, future developments in the concrete sector need to be implemented.

- CF reinforcements offer new design options and reduction of concrete use.
- LCA of vCF production shows high uncertainty due to lack of primary data and large range of literature data.

**Main findings from the EDISON-rCF project:**

- rCF from Solvolysis can be produced with a comparative low GWP. Preparation steps of used CFRP parts, such as sorting and comminution, have a minor impact.
- Application of rCF in carbon concrete can reduce potential environmental impacts in a short term compared to vCF.
- Taking into account the results of other EF3.1 LCIA categories, the interpretation is becoming more complex.

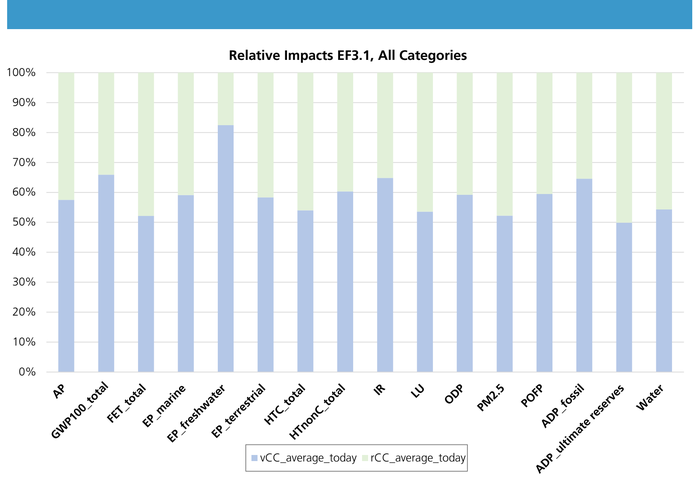


**Fig. 4: Relative environmental impacts** of chosen EF3.1 categories for the average vCC (blue) and rCC (green) models.**

*) *Preliminary results.* Modelled with Ecoinvent database v3.9.1 cut-off in Umberto LCA11 Software and EF3.1 LCIA Method. Transport, infrastructure and equipment omitted. Market datasets Germany (DE) for electricity of foreground processes and vCF production (scenario 'today'). Electricity Mix Germany 2030 based on optimistic data from German Institute for Economic Research DIW Berlin [3] (scenario '2030'). Concrete containing conventional Portland cement (CEM I) for today's perspective and blast furnace cement (CEM III) for 2030 scenario. Sensitivity analysis for energy consumption of vCF production, Solvolysis. Functional Unit (FU) is a reinforced concrete beam with a dimension of 250/200x550mm and similar mechanical performance obtained by varying the reinforcement content. A comparison of vCC and rCC with conventional steel reinforced concrete is not appropriate based on the current DAfStb guideline and is therefore not presented here. *Inventory data can be provided on request (partially aggregated).*

***) Corrigendum : The originally shown results have been based on a wrong entry in the model for the rebar production with vCF and led to underrated potential environmental impacts compared to rCF by a factor of 2.3. The corrected results are integrated in this online version.*

Sources:
[1] Bachmann, J. Challenges in the Life Cycle Assessment of fibre reinforced polymers using the example of a composite aircraft interior shell. EASN Conference 2023, Salerno, Italy
[2] Meng, F. Comparing Life Cycle Energy and Global Warming Potential of Carbon Fiber Composite Recycling Technologies and Waste Management Options. ACS Sustainable Chemistry & Engineering 2018 6 (8), 9854-9865, DOI: 10.1021/acssuschemeng.8b01026
[3] Kendziorski, M. Strommärkte nach Energiekrise stabilisiert – 80 Prozent erneuerbare Energien und Kohleausstieg bis 2030 erreichbar. DIW Wochenbericht 18 / 2024, S. 267-274

**EDISON-rCF - Energieeffizienter und werkstoffgerechter Recyclingprozess von carbonfaserverstärkten Kunststoffen von der Wertstoffaufbereitung bis hin zum neuen Bauteil unter Anwendung eines innovativen Solvolyseprozesses sowie der Entwicklung und Herstellung neuartiger standardisierter quasi-unidirektionaler Halbzeuge im industriellen Maßstab.**
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