

# Recovery of carbon fiber reinforced plastics from wind turbine rotor blades – current status and basic investigations

*Jonathan Mahl, Manuela Wexler, Werner Baumann, Manuela Hauser, Krassimir Garbev, Hans-Joachim Gehrman, Dieter Stapf*

Helmholtz Energy Conference  
Koblenz, 13.06.2023

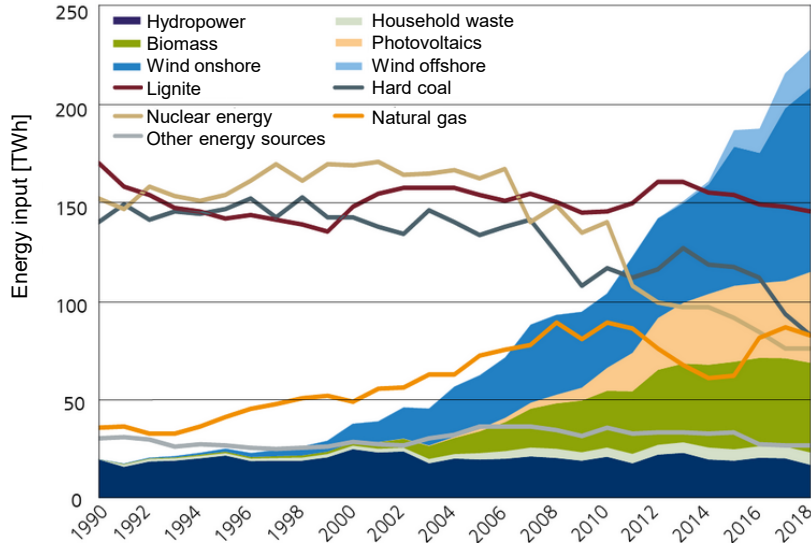


# Outline

- Background
  - Expansion of wind power
  - Rotorblade construction
  - Predicted CFRP waste volumes
  
- Recovery of CF/CFRP – current status
  - Recycling of CFRP
  - Energy recovery of CFRP
  
- Current research at ITC

# Background

## Expansion of wind power



## European Green Deal (2019):

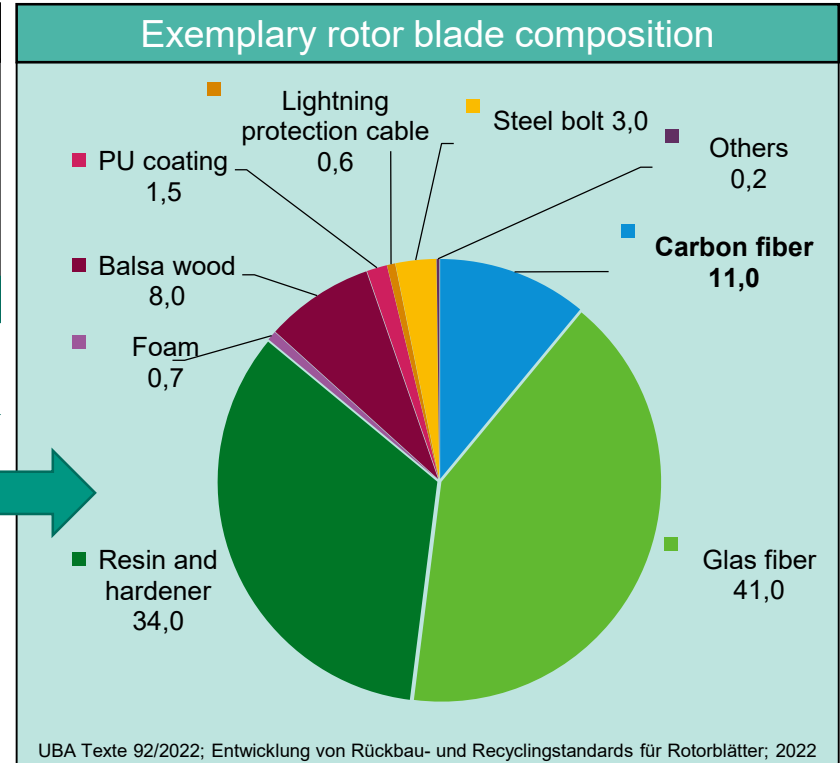
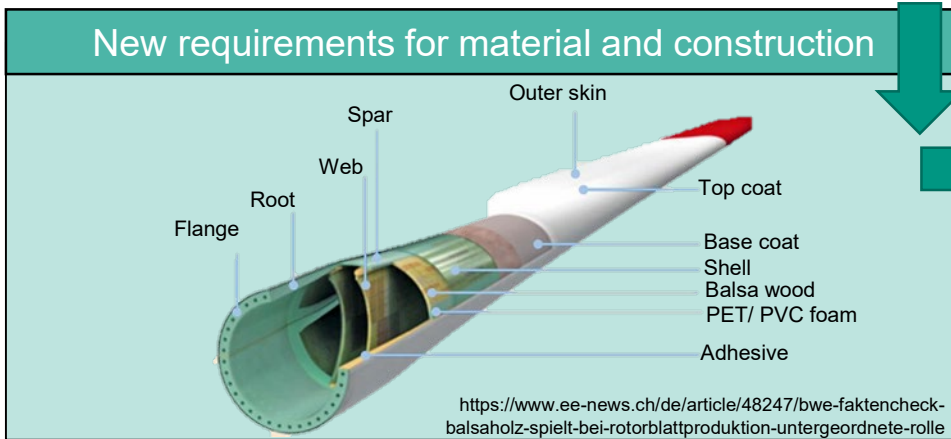
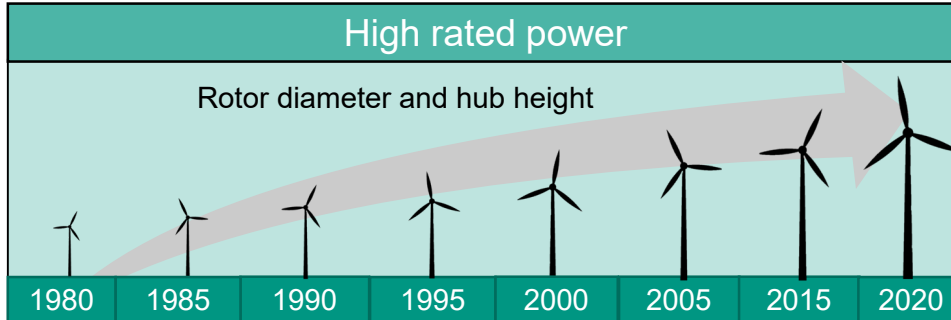
### Climate neutrality of the EU by 2050

- Expansion of renewable energy generation
- Reduction of greenhouse gas emissions
- Conservation of fossil raw materials

<https://www.iee.fraunhofer.de/de/presse-infothek/Presse-Medien/Pressemitteilungen/2019/windenergie-ausbau-stagniert.html>

# Background

## Expansion of wind power

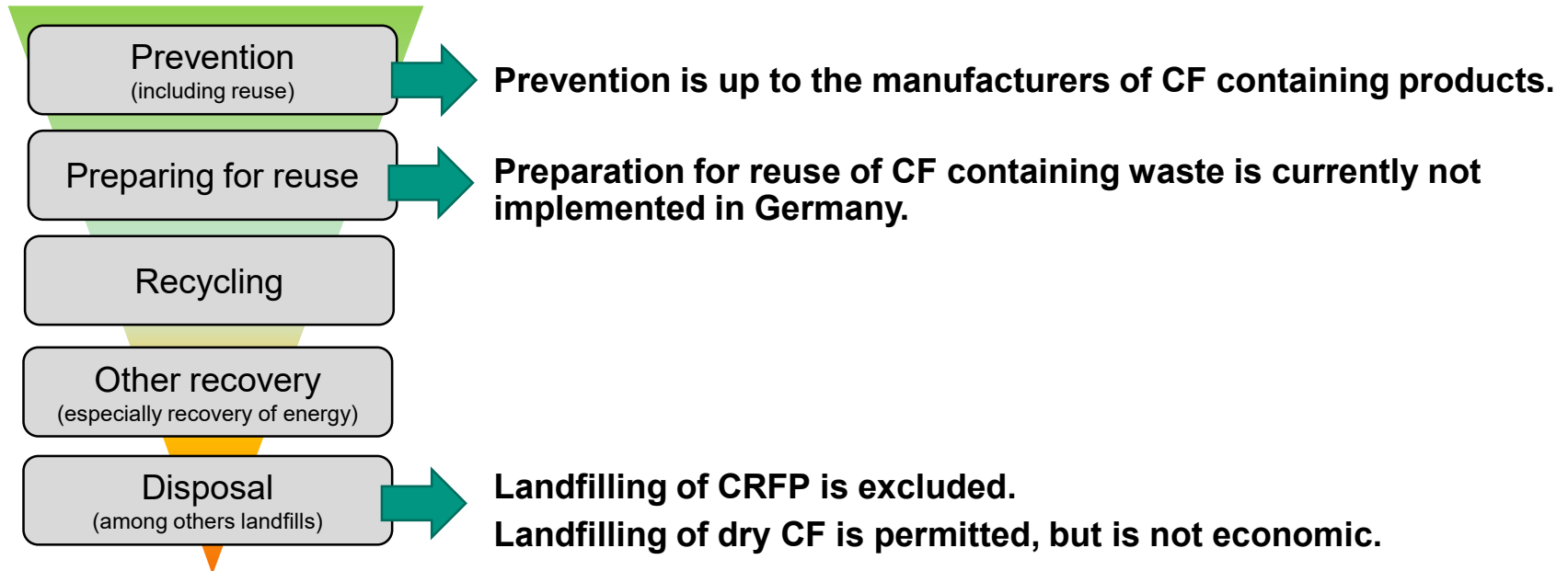


# Recovery of waste containing CF

## Framework

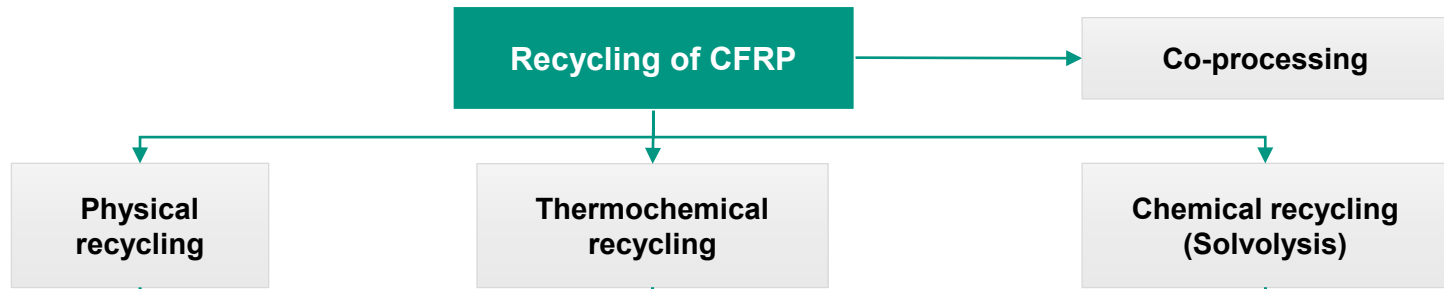
### Circular Economy Act (2012)

- Proper, save and high-quality recovery



# Recovery of waste containing CF – current status

## Recycling



	Particle-recycling	HV fragmentation	Pyrolysis	Microwave pyrolysis	Fluidized bed	Hydrolysis (water)	Glykolysis (alcohol)	Acid digestion (acid)
Spec. energy demand [MJ/kg]	0,27 – 2,03	4,3 – 89,1	23 - 30	5 - 10	6 - 30	19,2 - 91		
Tensile strength rCF [%]	~ 50	~ 83	~ 80	~ 80	~ 75	~ 95		
TRL	6 - 7	6	9	4	5 - 6	9 (South Korea)		

Source: UBA Texte 92/2022; Entwicklung von Rückbau- und Recyclingstandards für Rotorblätter; 2022

# Recovery of waste containing CF – current status

## Recovery of energy

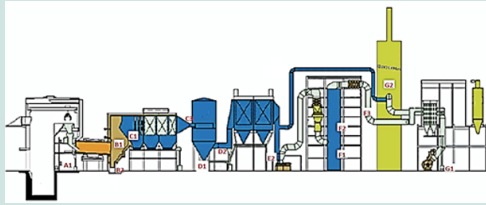
Umwelt  
Bundesamt  
UFO-Plan

### Waste incineration plant



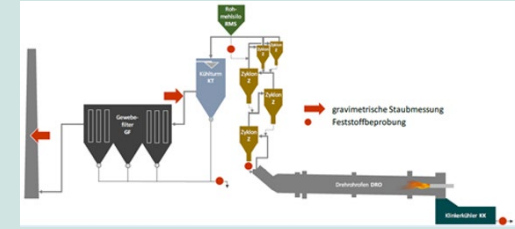
MHKW Coburg

### Hazardous waste incineration plant



SAV Biebesheim

### Cement plant



Cement plant Paderborn

Product	-	-	Cement
Temperature	900 - 1 300°C	ca. 900 – 1 200°C	≤ 1 450 °C
Atmosphere	Oxidizing	Oxidizing	Oxidizing
Duration	60 min	Hours	20 – 40 min

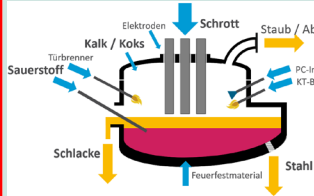
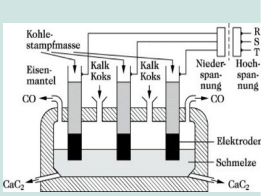
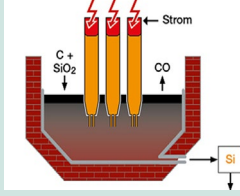
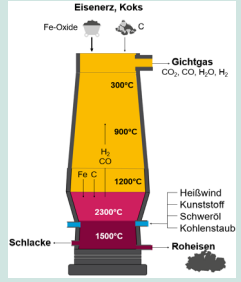

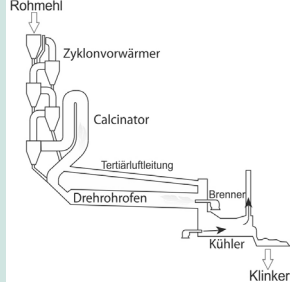


Process parameters at waste incineration plants and hazardous waste incineration plants were not sufficient for a complete thermal decomposition of CF

Source: UBA Texte 131/2021; Möglichkeiten und Grenzen der Entsorgung carbonfaserverstärkter Kunststoffabfälle in thermischen Prozessen; 2021

# Recovery of waste containing CF – current status

## Research question

	Electric arc furnace (EAF)		Blast furnace	Bath melting furnace	Cement plant	
		 <p>Spektrum der Wissenschaft, 1998</p>	 <p>www.chem2do.de</p>		 <p>J. I. R. Müller (2017)</p>	 <p>www.beton.wiki/images/1/13/Drehofen</p>
Product	Steel	Calciumcarbid	Silicium	Steel	Copper	Cement
Temperature	Ca. 1.600 °C	≥ 2.000 °C	Ca. 2.100 °C	Ca. 1.500 °C	Ca. 1.500 °C	≤ 1.450 °C
Atmosphere	Oxidizing	Oxidizing	Oxidizing	Oxidizing	Oxidizing	Oxidizing
Duration	ca. 40 min	Hours	Not specified	Hours	Not specified	20 – 40 min

Source: Wexler et. al.; Verwertung von Carbonfasern und carbonfaserverstärkten Kunststoffen bei der Stahlherstellung im Schmelzofen; 2020



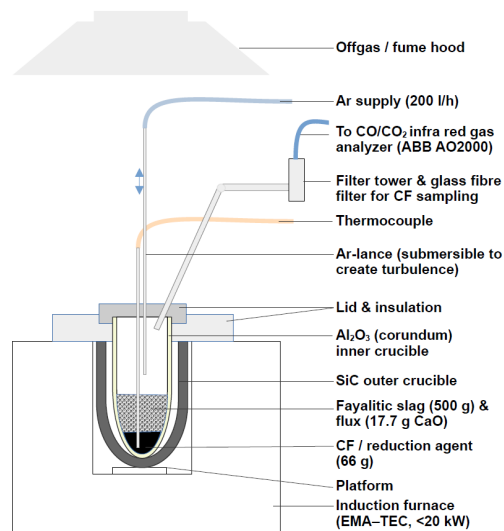
# Current research at ITC

CF recovery in the project „CarboFuel“



## “Utilization of carbon fiber reinforced composites in pyrometallurgical oxide systems”

- **Duration:** 01/2023 – 09/2026
- **Funding reference:** L7518017
- **Working packages**
  - Selection & characterisation of materials and systems
    - Different CF
    - Inert and reactive slag systems
  - Crucible tests in lab-scale furnace
    - Influence of slag system, temperature, turbulence
  - Lab- and pilot-scale experiments in a bath smelting furnace (TSL reactor)



*First promising results with various CF in fayalitic slag are available:  
Proceedings of the 61st Conference of Metallurgists, COM 2022*

# Summary

- Increasing amount of installed wind turbines  
→ increasing amount of CF containing waste is expected.
- Pyrolysis is the only commercial available recycling process for CFRP waste in Europe.
- No process for the recovery of CF, that cannot be recycled anymore, is available yet.
  
- Project „CarboFuel“: Utilization of carbon fiber reinforced composites in pyrometallurgical oxide systems”
- The utilization of CF as a reduction agent in the fayalitic copper slag treatment to substitute fossil based reduction agents was successfully shown in crucible tests.  
→ Investigations in a lab scale and pilot scale TSL reactor are planned.

# Thank you for your attention!



Institute for Technical Chemistry  
Karlsruhe Institute of Technology  
Hermann-von-Helmholtz-Platz 1,  
76344 Eggenstein-Leopoldshafen

E-Mail: [jonathan.mahl@kit.edu](mailto:jonathan.mahl@kit.edu)  
Tel. 0721 806 23832