Experimental Analysis of the Solvolysis and Oxidative Liquefaction of the End-of-Life Composite Wastes

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Outline of the Presentation

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3. Recycling
4. Proposed solution: solvolysis and oxidative liquefaction
5. Aim of the work
6. Properties and experimental stan
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Problem statement

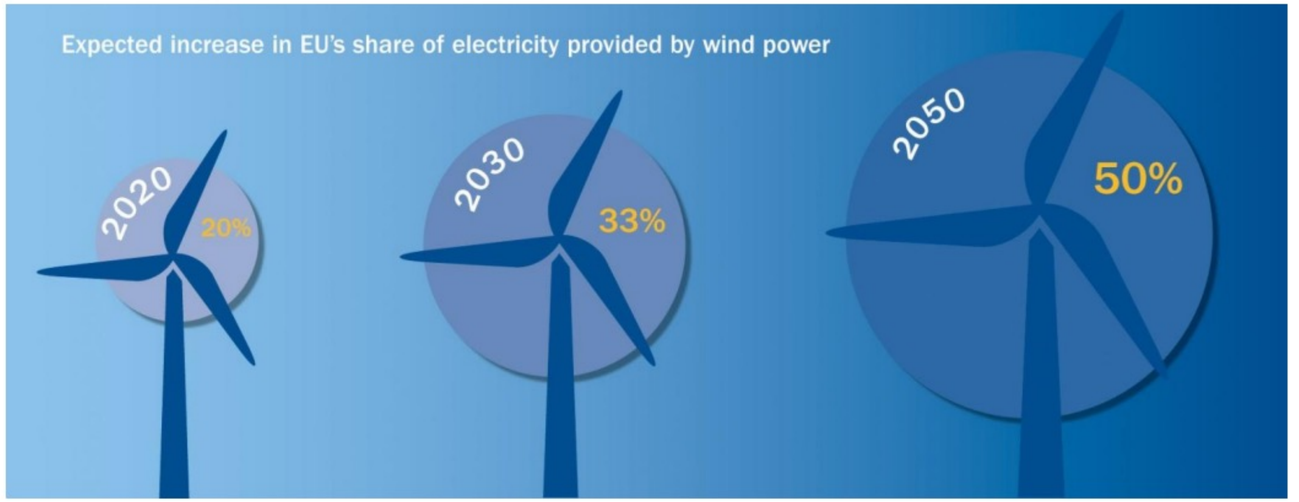
Increasing energy demand

Use of renewable energy resources

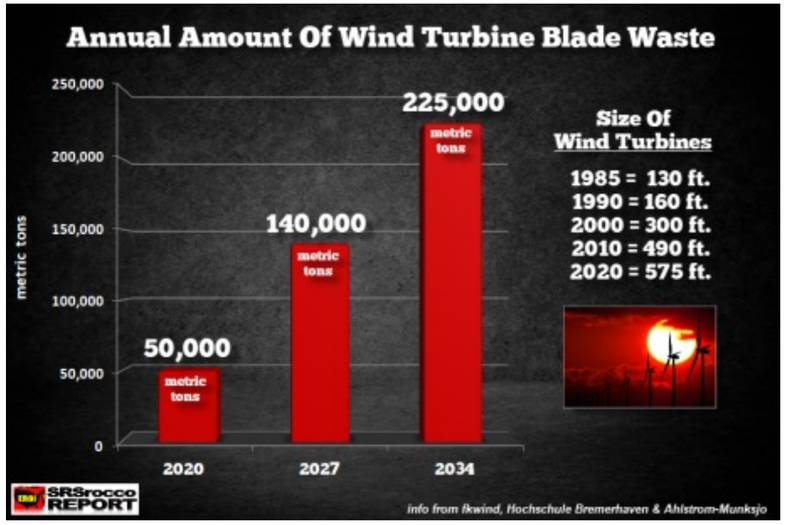
End-of-life wind turbine blades

Wind turbine blades probelm

Aerial view of a turbine blade graveyard



Rotterdam's Wikado playground has found a use for old turbine blades



Wind turbine blades probelm

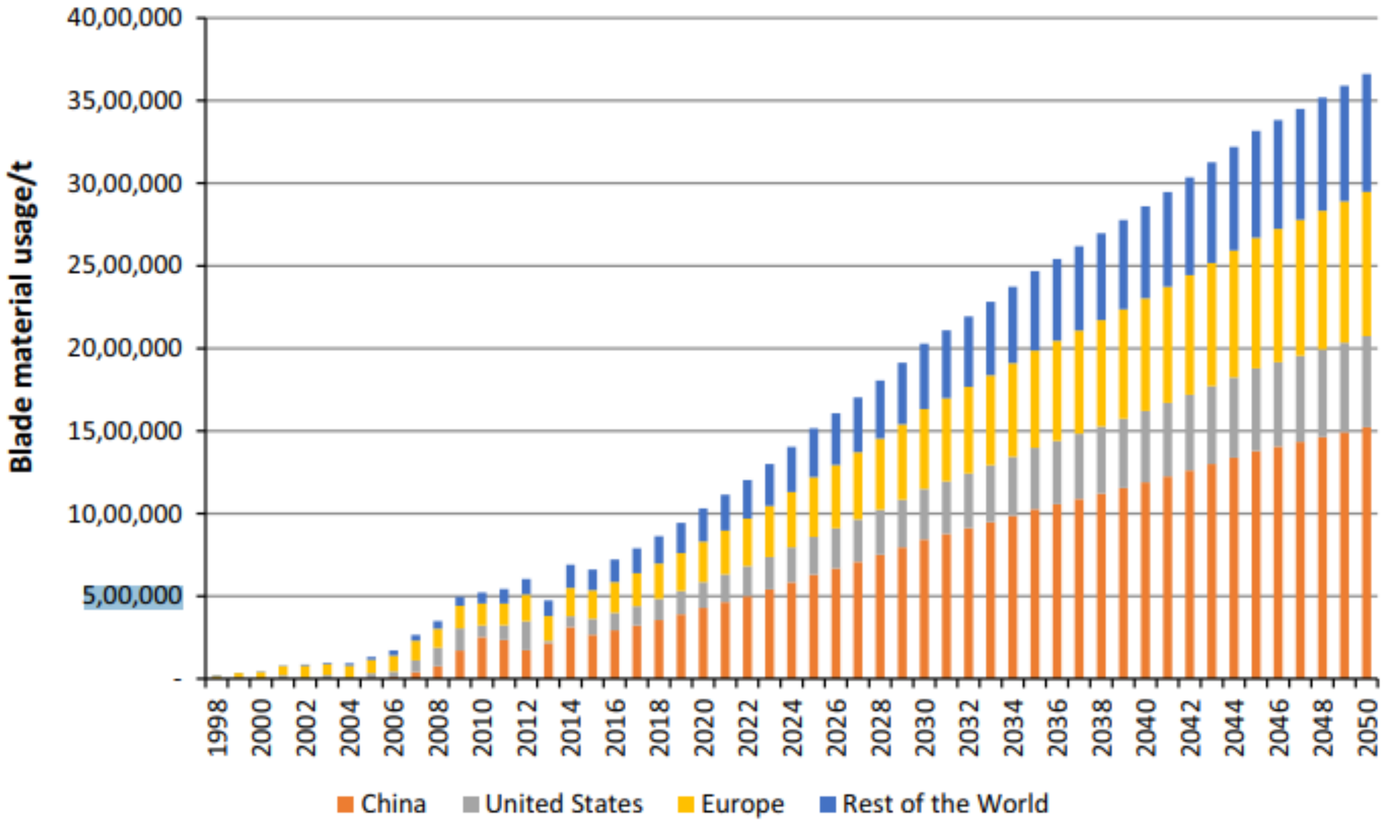
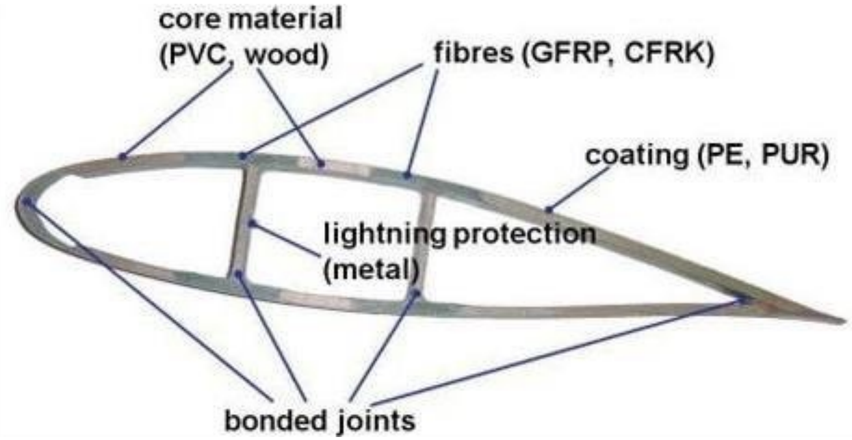


Fig. 6. Annual WTB material usage. Data after 2014 is calculated based on the moderate growth rate scenario.

Wind turbine blades have complex composition and it's not an easy task to separate their components so the premise for recycling is a mixed waste stream where little is known about the chemical composition.



GFRP, CFRK Glass/Carbon Fiber Reinforced Polymer

Recyckling

As per the hierarchy established by the EU Waste Framework Directive, it is recommended to **avoid the disposal of waste materials** in a manner that does not allow for the recovery of any potential energy or material value.

The production of wind farms is resource-intensive and requires the use of non-renewable chemicals, which can have a significant environmental impact. Therefore, it is crucial to **recycle wind turbine components**, not only to mitigate their environmental impact but also to recover energy and valuable materials such as GFs and resin monomers from waste composites.

Proposed solution

Oxidative Liquefaction

- Conversion of high molecular weight organic compounds into low molecular weight carboxylic acids in the presence of oxidate agent at moderate temperature and Pressure.
- During the process, waste is degraded in water under subcritical conditions of temperature (250 to 350 °C) and pressure (20 to 150 bar). A reactor vessel is pressurized using nitrogen to maintain its contents in a liquid state.

Solvolysis

The term solvolysis implies a technique to use a reactive solvent to break the covalent bonds of a polymer matrix. As a result, the polymer matrix monomers and decomposition products, whose ratios are dependent on the process conditions, are mixed with the solvent to form a liquid product, while the fibers are separated and freed from the matrix structure.

The frequently used solvents, in descending order of prevalence, are water, ethanol, methanol, propanol, and acetone, in addition to their mixtures

Oxidative liquefaction (OL)

The OL experiments were carried out in batch-type reactor at temperature ranges of 250-350°C, pressure 20-40 bar, residence time of 30-90 minutes, H_2O_2 concentrations of 15-45%, and waste/liquid ratio of 5 to 25%. Wind turbine blades were cut mechanically into small pieces varying in size between 1-2 cm and mixed with water and hydrogen peroxide in suitable proportion according to the experimental conditions. Parr 4650 reactor was used to carry out the experiments at a set temperature and pressure conditions. Nitrogen gas played its role to provide an inert environment and maintain the required pressure inside the reactor

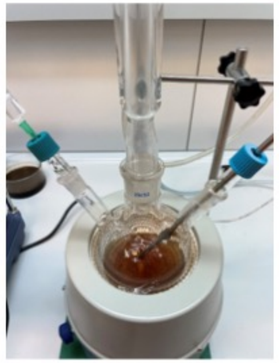
Solvolysis (SOL)

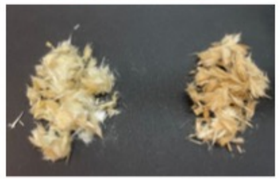
The SOL was carried out in a batch reactor of 1 dm^3 volume. The process temperature was maintained at 190°C at pressureless conditions, with the addition of the 0.0125 mol of triazabicyclodecene (TBD) catalyst in the ethylene glycol solution. The total solvolysis process time was 6 hours

Aim of the work

This paper presents results of the solvolysis (SOL) and oxidative liquefaction (OL) process of epoxy resins and glass fiber reinforced plastics (GRP) that are a major portion of the end-of-life (EoL) wind turbine blade and carbon fiber (CF) and glass fiber (GC) reinforced composites.



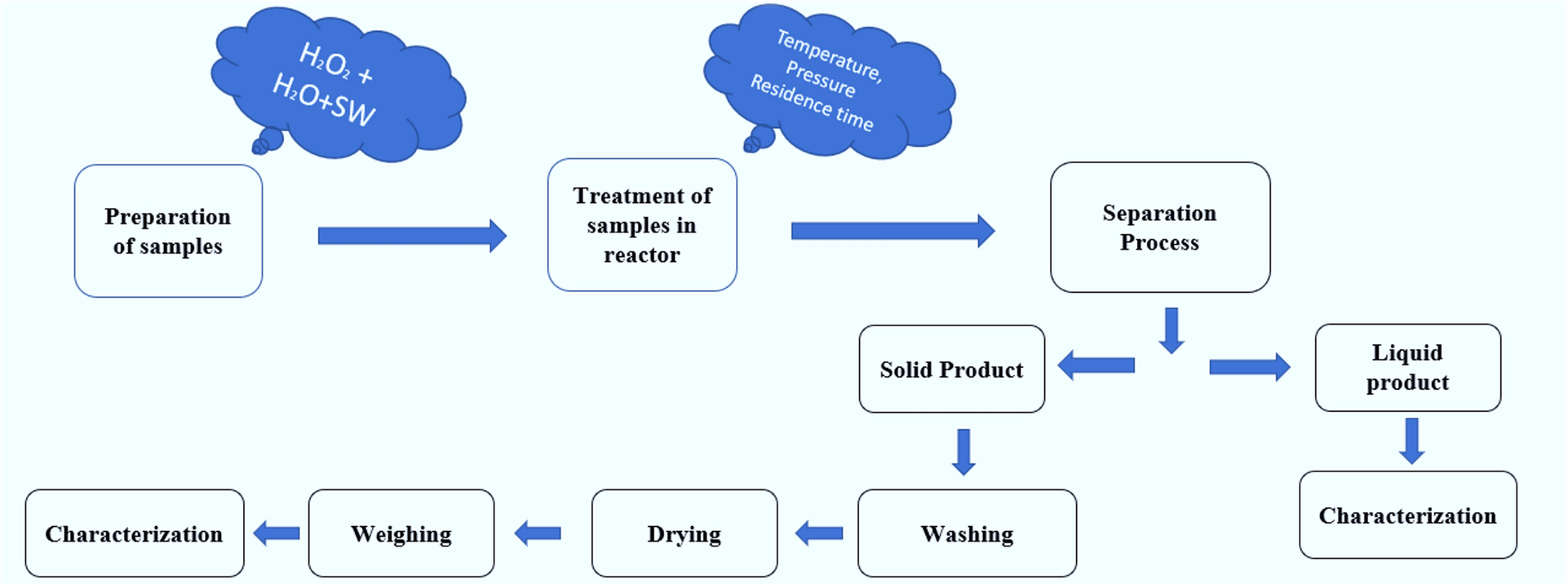







DANGER
HOT SURFACES
HIGH PRESSURES


Experimental methodology



Ultimate and proximate analysis results of the WTB sample

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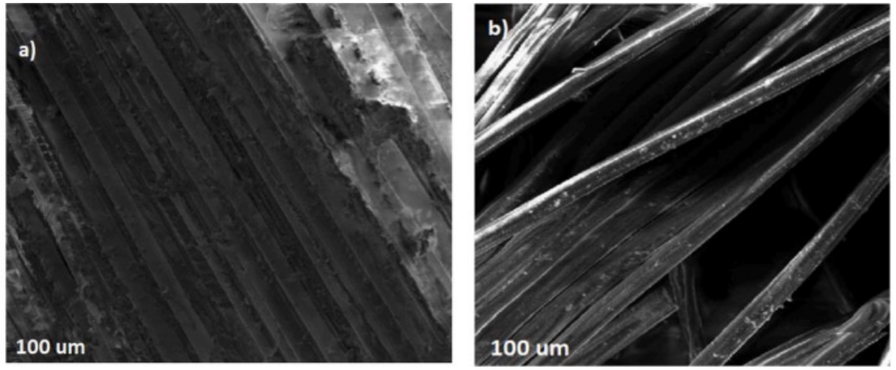
Ultimate analysis, wt.%[daf]	$U(X)$
C	69.7 ± 8.0
H	7.3 ± 1.1
N	3.0 ± 0.5
O [diff.]	19.8 ± 1.7
S	<0.5
Proximate analysis, wt.%	
Moisture	1.3 ± 0.7
Volatile matter[d]	58.7 ± 0.3
Ash[d]	41.2 ± 0.2
Fixed Carbon[diff.]	<0.5

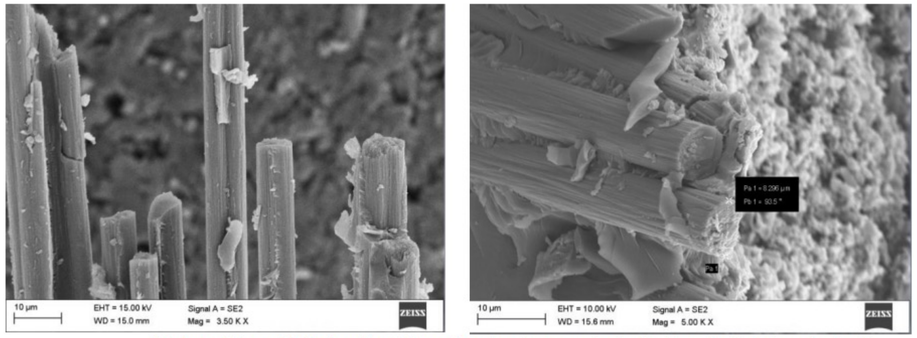
[diff] Calculated as a difference.
[d] Dry state.
[daf] Dry ash free.

Microstructure of the raw WTBs before and after oxidative liquefaction



SEM images - surface morphology of glass fibers: a) resin matrix fibers; b) fibers after the oxidative liquefaction process.

Shows the morphology of the GFs obtained for the sample with maximum resin degradation after the oxidative liquefaction process, i.e., the removal of the polymer matrix from the fiber surface. Single and well-separated GFs can be seen. The morphology of the glass fiber surface confirms that it is smooth and free of obvious discontinuities, indicating that the SiO2 layer produced is of high quality. Locally, a few irregularities and minor impurities, which are products of resin decomposition, are observed



Carbon fibers (CF) / resins taken for structure analysis during the batch solvolysis process (SEM images).

Scanning electron microscope observations on the samples taken during the batch solvolysis process show that the process ran successively. The basic mechanism enabling gradual and deeper penetration of a chemically active solution in this case is surface degradation

Conclusions

- The oxidative liquefaction and solvolysis of WTBs appears to be a promising technique for effectively degrading the polymer matrix and achieving higher values of WTB resin degradation yields.
- Both techniques are a promising method of utilizing challenging composite waste materials.
- Both methods fulfill the principles of a circular economy.
- Currently, research is being conducted to examine the influence of fundamental process parameters such as pressure, temperature, type and quantity of reagents, as well as waste parameters on the efficiency of the processes.

An experimental investigation and process optimization of the oxidative liquefaction process as the recycling method of the end-of-life wind turbine blades

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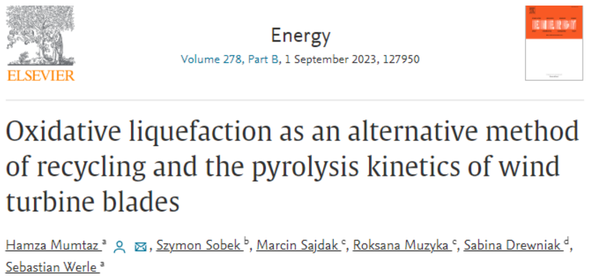

Acknowledgment

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THANK YOU

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