

PYROPLAN

Pyrolysis of Wind Turbine Blades

A feasibility study



- CONFIDENTIAL -

Triple Benefit - December 2012

Rik Voerman – info@triplebenefit.nl

© Triple Benefit, December 2012

Confidential - This report is confidential and proprietary and may not be reproduced in whole or part unless authorized in writing by an authorized representative of Triple Benefit.

Disclaimer - This report is a sample and not intended to represent any specific process design. It is a compilation of different sources and any discrepancies in the comments and associated values used in this report are not typical. The values used in this report are not intended to be actual or representative of factual calculations and are used in this report to represent “placeholders” only.

Management summary

The annual volume of composite waste is growing substantially, driven by growing sectors like the Wind power, Automotive and Aviation industries.

Pyrolysis of composite materials has shown to be a technically proven process at small scale, and several companies around the world have been developing the process on a larger scale recently. Nevertheless the processes are hard to get profitable. For that reason processes regenerating *carbon* fibers rather than glass fibers only have gained most attention up to now.

The process of composite pyrolysis shows strong parallels with BIO-oil production, that is currently being further developed and expanded by multiple parties in the world. Compared to these processes, the pyrolysis of turbine blade composites shows several interesting advantages:

- Less water content of feedstock, resulting in more efficient processing
- More homogeneous feedstock, resulting in better controllable output properties
- Potentially no feedstock costs but revenues instead
- Potentially higher added value of specific components/pieces when reused

Nevertheless, specifically for wind turbine blades, additional practical issues arise like the absence of carbon fibers in most blades and efficiently partitioning the blade. These aspects make the process potentially less economically viable. To develop a sustainable pyrolysis recycling process for wind turbine blades, at least some of the following points are to be addressed:

- The processing costs should be partially subsidized by the supplier, paying a disposal fee of approximately 50% of the landfill costs
- The reuse of components/pieces should provide satisfactory revenues
- The regeneration and reuse of glass fibers should provide satisfactory revenues
- Strong industrial or governmental parties should provide substantial financial support during the start-up years in order to attain a economically viable process

Apart from financial points of attention for exploitation, the following aspects are critical:

- Technical challenges
- Environmental licenses
- Logistics
- Supplying and consuming parties
- Health and safety

1 Inhoud

2	Introduction	6
2.1	Disposal of Wind Turbine Blades.....	6
2.2	Opportunities for the composites sector	7
2.3	The status of pyrolysis.....	7
2.3.1	BIO-pyrolysis	7
2.3.2	Recovering Carbon fibers	8
2.3.3	Degrading turbine blades.....	8
2.3.4	Competitive processes	8
2.4	Definitions	8
3	Disposing and processing of composite wastes	9
3.1	Land fill.....	9
3.2	Shredding to a filler material.....	9
3.3	Holcim process.....	9
3.4	Degradation technologies.....	10
3.5	Benefits of pyrolysis	11
3.6	Upcycling	11
4	The pyrolysis proces	12
4.1	Functional process description of pyrolysis	12
4.2	Composition of pyrolysis output.....	13
4.3	Pyrolysis of epoxy	14
4.3.1	Chemical formula of epoxies.....	14
4.3.2	Temperature range	14
4.3.3	Heating and cooling rate.....	15
4.3.4	Water content	15
4.3.5	Heating energy	15
4.4	Products of composites pyrolysis	15
4.4.1	Resulting gases	16
4.4.2	Phenol	16
4.4.3	Fibers.....	17
4.5	Pyrolysis of other raw materials.....	18
4.5.1	Polystyrene (PS).....	18
4.5.2	Pulyurethane (PU)	19
4.5.3	Styrene Acylonitril (SAN)	19
4.5.4	Polyethylene Terephthalate (PET).....	19
4.5.5	Polyvinylchloride (PVC)	19
4.5.6	Balsa.....	20
4.5.7	Production waste	20
4.6	Health and safety	20
4.7	Conclusions	21
5	Potential benefits of pyrolysis	22
5.1	Potential yield of Wind Turbine Blades	22
5.1.1	Blade decomposition	22
5.1.2	Reuse of the shear webs.....	23
5.1.3	Process output.....	23
5.2	Energy consumption.....	24
5.2.1	Needed process heat.....	24
5.2.2	Heat obtained from the process.....	24
5.3	Thermal processing window	24
5.3.1	Degree of decomposition.....	25
5.3.2	Chemical composition of oil	25
5.3.3	Chemical composition of gas.....	25

5.3.4	Fiber quality	25
5.4	Expected costs of processing	25
5.5	Potential revenues of processing	26
5.6	Conclusions	26
6	Technical process description	27
6.1	Process steps	28
6.1.1	Blade cutting and handling	28
6.1.2	Milling / shredding	30
6.1.3	Heating and cracking in a reactor	31
6.1.4	In-process vapor treatment	38
6.1.5	Electrical power generation	39
6.1.6	Oil refinery	40
6.1.7	Fiber recovery	40
6.1.8	Logistics and lay-out requirements	40
6.2	Processing speed and capacity	41
6.3	Environment, health and safety	41
6.3.1	Toxicity of oil	41
6.3.2	Acidity of oil	41
6.3.3	Inflammability	41
6.3.4	Dust production	41
6.3.5	Environmental impact	41
6.4	Investment	41
6.5	Conclusions	42
6.6	Remaining issues to be elaborated	42
7	Roadmap	43
7.1	Step one: Making logistics work	43
7.2	Step two: Pyrolysis pilot plant with combustion	44
7.3	Step three: Recovery of fibers	45
7.4	Step four: Improving for optimal refinery	46
7.5	Step five: Upscaling the process	46
8	Conclusions	47
9	References	48
9.1	Papers	48
9.2	Internet	48
9.3	Other references	49
10	Appendix	53
10.1	Patents and IPR	53
10.2	Energy Balance Refiber	54
10.3	Exploitation Step 1	55
10.4	Exploitation Step 2	56
10.5	Exploitation Step 3	57