Research note outline on recycling wind turbines blades

Contents

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1 Scope of the research note

The EU binding target of increasing renewables share by 20% to 2020 and Europe's commitments to cut the GHGs by 80-95% by 2050 makes wind energy an important player in the future energy mix. At the end of 2010, 5.3 % of EU's electricity demand was met by wind energy. According to EWEA scenarios, by 2020 the percentage will increase to 15.7%, by 2030 the share will reach 28.5% and by 2050 wind's share in total electricity consumption will be 50%. In terms of capacity installed, this translates to 230 GW of wind power by 2020, of which 40 GW offshore, 400 GW by 2030 with 150 GW offshore, while by 2050 – 735 GW are forecast, mostly, 460 GW, offshore.

Moreover, the number of wind turbines installed can be an effective indicator of the development of the wind industry. Currently, there are approximately 70,000 turbines installed in Europe with a 20-year project life time on average and 3,300 units installed annually. A growing amount of wind turbines will start to be decommissioned, considering that:

- the standard lifetime of a wind turbine is approximately 20-25 years
- there are increased opportunities for repowering i.e. replacing old models with newer and more efficient machines.

A sustainable process of dealing with the turbines at the end of their life is needed in order to maximise the environmental benefits of wind energy through a lifecycle approach. Most of the parts of a wind turbine such as foundation, tower, components of the gear box and generator -- are already recyclable and treated accordingly. Nevertheless, rotor blades represent a challenge due to the complexity of their composition and materials used.

The objective of the research note is to assess the different methods used in recycling wind turbine blades, in terms of cost and sustainability. Important sources of information are the wind turbine manufacturers, wind power developers, recycling companies as well as companies that utilise the end-product of recycling.

2 Methodology/Approach

The methodology applied for this research note is:

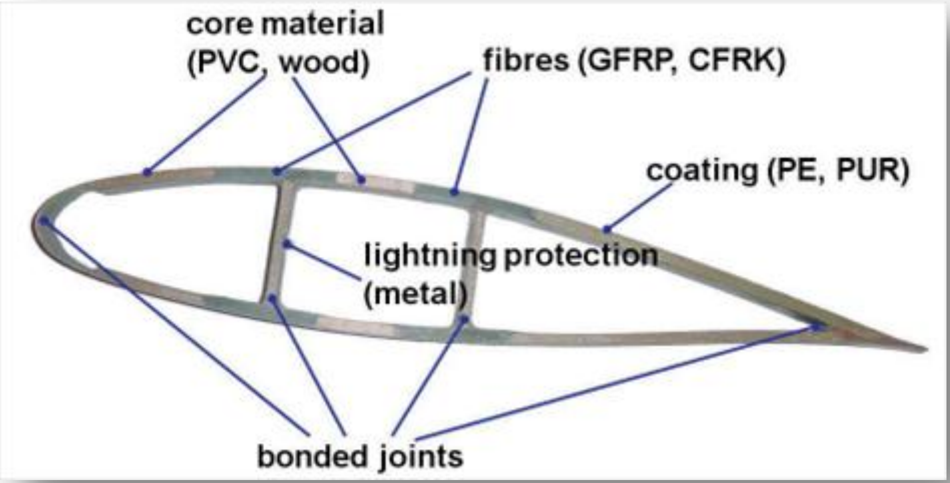
- a thorough literature review was made in order to determine the state of development of the process of recycling wind turbine (WTs) blades at European level.
- phone interviews and information exchange with some of the companies developing activities in the field of recycling WTs blades, notably Re-Fiber (DK) and Zajons (DE).

3 Results

3.1 Technical description including the state of development

Turbine blades consist of different materials: fibre reinforced plastics made of carbon or glass fibres which are held together by synthetic resin (FRP), metal, wood, and plastic (used as core material and coating). Figure 1 below shows the main components of a rotor blade.

Figure 1: Cross section of a rotor blade



The main materials used for blades, the FRPs fall under the category of materials called composites. The amount of FRP used in wind turbines is 10-15 t/MW[1]. The main reason for which FRPs are used in wind turbines is that they present advantages compared to other materials:

- They allow an aerodynamic design and are lighter (compared to steel rotor blades, for instance).
- Lightning protectors and heating systems to prevent ice formation can be easily integrated into blades made of glass fibre or carbon fibre.
- They have excellent corrosion properties, particularly relevant for a fast developing offshore sector.

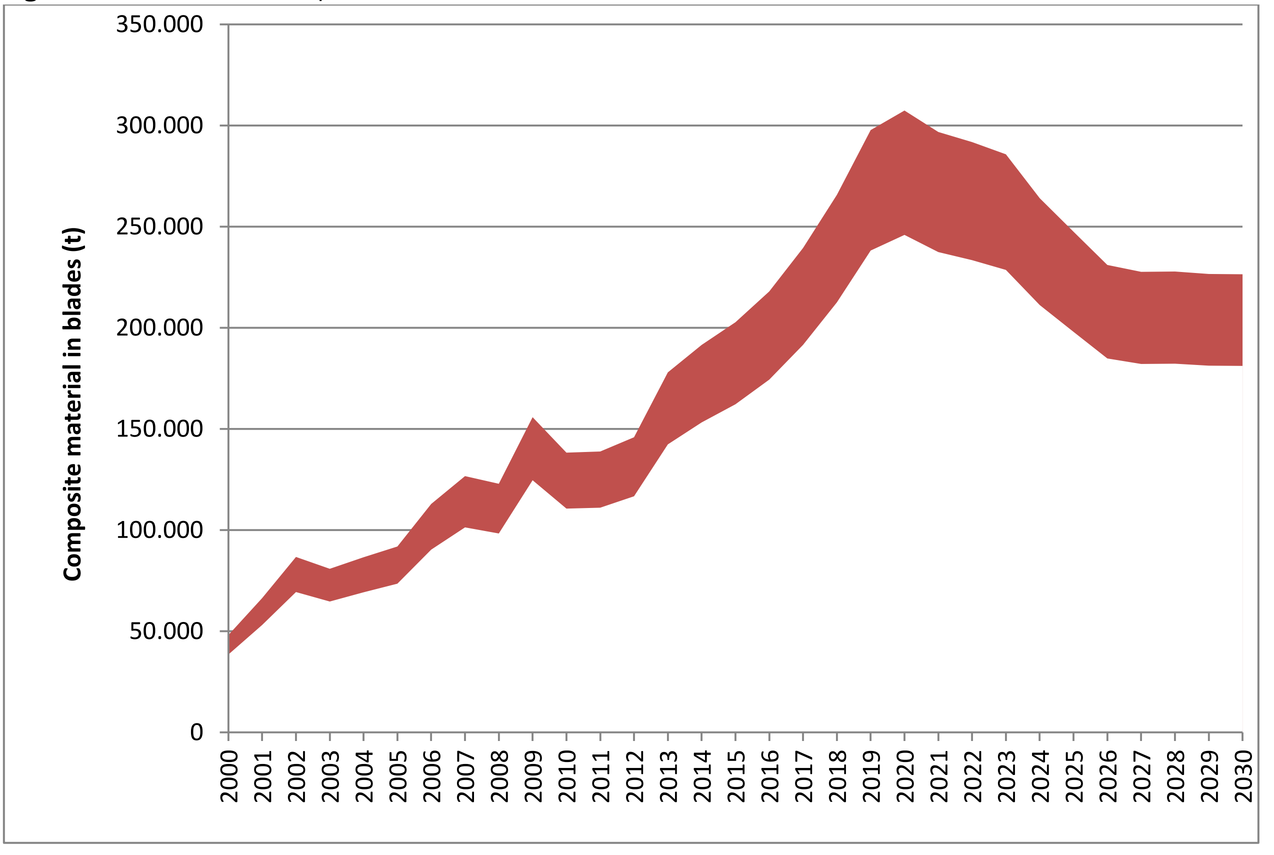
As regards the decommissioning of a wind power plant, most of the materials used can be recycled. For the wind turbine blades, materials such as metals, wood and some plastics can be recycled as well. Nevertheless, recycling composites remains a challenge due to a number of technical and legislative reasons even though the technology for recycling composite parts of wind turbine blades exists, albeit at small and regional scale. The main reasons for the small development of this sector so far are:

- The value of the recycled product,
- The small amount of input (blade waste)currently into place, which does not stimulate the recycling market,
- Little development or lack of adequate legislative framework for the disposal of wind turbine blades.

[1] ReFiber ApS 2010 report.

Considering the current and foreseen development of wind energy, the amount of composite waste from the wind industry is expected to increase. Assuming that the amount of composite material used in wind turbines is between 12 and 15 tonnes per MW, we can see in the following graph the annual use of composites for the period 2000-2030.

Figure 2: annual use of composite material in wind turbine blades

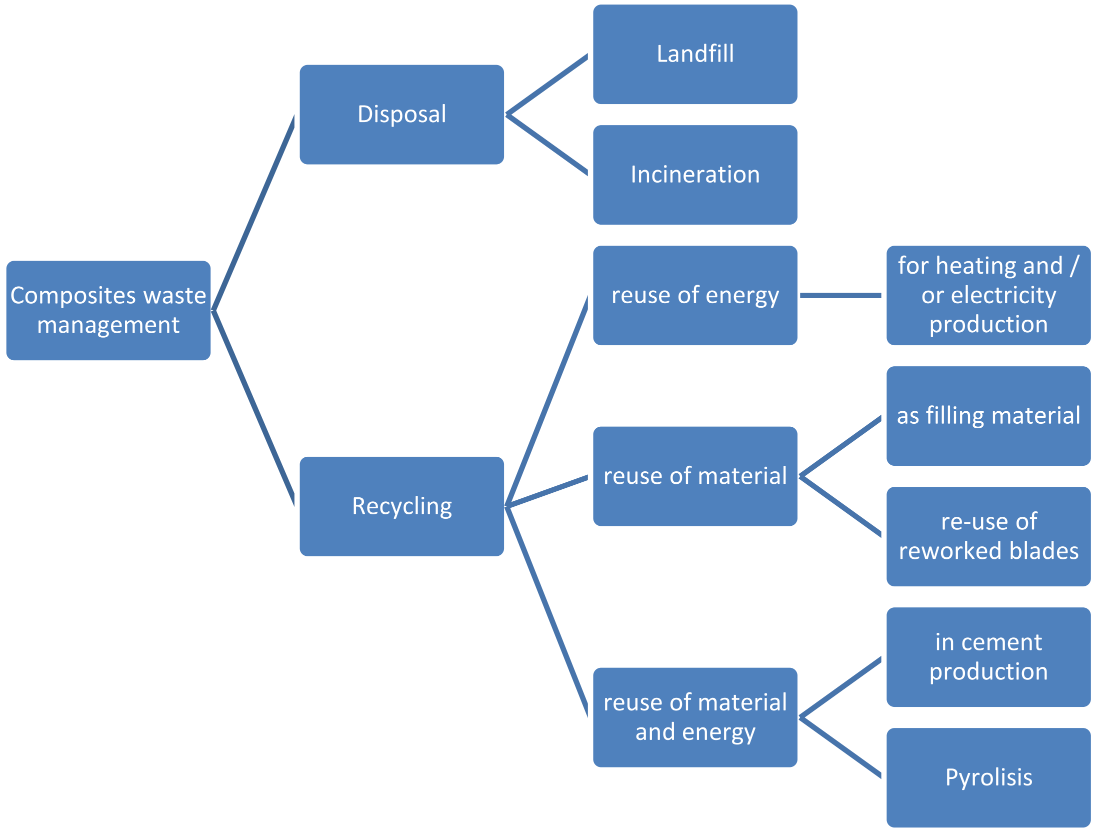


Based on the installed capacity, in 2000, the use of composites for wind turbine blades was around 50,000t. In 2010, between 110 and 140 kt of composites were used by the wind turbine industry. Large amounts of composites are expected to be recycled. The current scale of facilities cannot accommodate the expected amount of composite waste in the near future. The need to further develop and up-scale existing methods and capacity is expected to become even more obvious over the next 5 years.

3.2 Composites waste management

The current available methods for disposal and recycling of wind turbines are shown in the graph below and described in this section.

Figure 3: Disposal and recycling options for blades



Disposal

a) **Landfill:** currently landfill represents the cheapest option. Legislation can act as a driver in some cases for the development of alternative solutions (creation of a recycling market).For example in Germany composites were banned from landfilling, on 1 June 2005; in UK it is still allowed, however the landfill tax is £48/t.

b) **Incineration:** the advantage is that there are already numerous facilities in place (incineration plants) and that it can be done at attractive prices. The disadvantage is that no large parts can be incinerated; and that it has high ash content (around 50%) that needs to be landfilled afterwards, and it also has slag residues that can cause problems in the flue gas cleaning system.

Recycling

c) **Reuse:** the advantage is that it has an economic value but it is hard to apply due to the different types of fibres/ingredients, the purity of the materials and the small quantities.

d) **Pyrolysis**: the advantage is that fibre structure can be recovered at a great extent. For the moment, this solution is expensive and not used on a large scale.

e) **Cement plants:** it is a cheap solution and offers a 100% recovery rate, the disadvantage is that considerable preparation is necessary and a special formula is needed.

Industrial solutions implementing some of the concepts already presented, have been identified and are analysed below.

3.2.1 Geocycle/Zajons solution (co-processing)[2]

Holcim AG/Geocycle together with Zajons developed a new recycling system. The idea was to create an industrial waste disposal solution for large components of fibre-reinforced plastics (GFRP and CFRP) which ensures a complete thermal and material recovery during the production process of cement clinker. According to assessments made by German experts, prior to the Zajons/Geocycle solution there was no practicable disposal method for rotor blades mainly because of inadequate logistics, health & safety and environmental risks (dust and solvent emissions).
The process presumes the following steps:

- fragmentation of large components into easily transportable pieces at source/on site, avoids transportation costs of heavy components and administrative procedures;
- separation of secondary raw materials in the further treatment;
- 100% thermal and material recycling;
- maximum dust reduction at all processing steps.

The project "*Sustainable recycling of used rotor blades in the cement plant Lagerdof*" was launched by Geocycle[3] in 2008. In 2009, Geocycle started initial processing trials with fibre-reinforced components, in partnership with Zajons. In 2010 the approval for the processing plant was obtained. The investment was of around €6 million, and the installation has a capacity of 60.000 t/a.

The recycling process comprises dry mechanical treatment, separation of secondary raw materials (metals), homogenisation to substitute and replacement of primary raw materials.

With this solution the company has achieved the following environmental and economic benefits:

- 100% recovery guarantee and unique sustainable recycling system;
- contribution to climate protection by reducing CO2 emissions (using waste as a fuel instead of fossil fuels);
- utilisation of the ash from rotor blades as an alternative raw material and the substitution of primary fuels (e.g. coal) contributes to the protection of natural resources. The rotor blade ash contains high quantities of silica and calcium, two of the main components of a high quality clinker;
- it is a waste free process due to the thermal and material utilisation in the cement plant, meaning the process has a high level of sustainability which helps avoid waste;
- cost-effective logistics through mobile sawing;
- a fixed price is paid for used rotor blades which enables better planning;

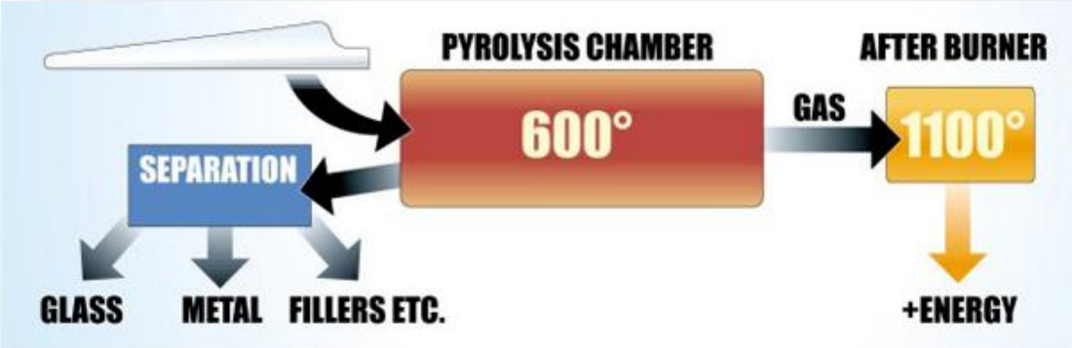
3.2.2 ReFiber solution[4]

ReFiber ApS has developed and patented a concept for recycling GFRP and CFRP. The ReFiber process makes use of the pyrolysis method (thermal treatment); this recycling concept occurs with the **recovery of energy** (the gas obtained throughout the process is burned in CHP plants used in district heating) and **the reuse of materials** (the glass fibres are processed for final use as new raw materials, such as wool for insulating purposes, short fibres for reinforcing casting compounds, plastic items, high strengthen concrete etc.). According to ReFiber, 3 Metric tons of fibregalss composite returns as much energy as 1 Metric ton of fuel oil.

Wind turbine blades and other glass fibre items typically are composed up to 50 - 60 % glass fibres. If such materials are burned in ordinary waste incineration ovens - the glass material will end up in the general slag fraction. Slag[5] from household waste typically contains heavy metals and must be deposited in secured areas to avoid further pollution of the environment. When worn out wind turbine blades are sent to municipal incineration facilities, the glass fibre material is mixed with the polluted slag from household waste incineration. The ReFiber process leaves no residues when treating the wind turbine blades through gasification, as explained below.

[2] http://www.zajons-logistik.de/
[3] http://www.iswa.org/uploads/tx_iswaknowledgebase/Schmidl.pdf
[4] http://www.refiber.com/technology.html
[5] Residual from burning process

Figure 4 ReFiber concept in short: gasifying the plastic and refining the glass fibres[6]



Steps in the technological ReFiber process:

- large structures, like wind turbine blades are cut on sites with a hydraulic shear
- the cut material is transported to the recycling facility
- cut composites material and production waste is shredded to reduce size to maximum 25cm*25cm
- the material is fed into a pyrolysis rotary kiln for gasification at 500°C; the gas is burned in a separate furnace at 1100 ºC or in a CHP radial gas turbine for electricity production. During this procedure around 50% of the fibre strength is lost.
- the metals, fillers and glass fibres are recovered and separated; the glass fibre is combined with polypropylene fibres creating stable insulation slab.

Figure 5 Insulation wool mat made out of blade fibre

3.3 Overview on the market and relevant framework conditions

According to a report by AVK Federation of Reinforced Plastics in November 2010, named "Sustainability of Fibre Reinforced Plastics"[7] wind turbines are a major user of FRP. The increase in wind turbine size (especially for the offshore sector) and the installation of new wind farms across Europe assures the creation of a strong market for GRPs.

3.3.1 The Glass Fibre market

According to AVK Composites market report 2011[8] the production volume of glass fibre in Europe in 2011 has returned to the 2008 level at 1,049 million tonnes.

[6] http://www.renewableenergyfocus.com/view/319/recycling-wind/
[7] http://www.avk-tv.de/files/20110915_nachhaltigkeit_von_faserverbundwerkunststoffen_eng_101115_4.pdf
[8] http://www.avk-tv.de/files/20110929_marktbericht_2011_englisch.pdf

Table 1: Distribution of glass fibre annual production by country, 2008 - 2011. The 2011 figure is estimated, and Eastern Europe means: PL, CZ, HU, RO, LV, LT, SK, SI, Serbia, Croatia and FYROM.

Glass fibre annual production (kt)					
Country	**2008**	**2009**	**2010****	**2011***	**Increase/Decrease rate against 2008**
UK/IE	123	106	130	126	2%
BE/NL/LU	38	31	40	42	10%
FI/SE/DK/Norway	69	52	50	52	-33%
ES/PT	236	188	217	200	-18%
IT	183	122	154	165	-11%
FR	115	87	116	122	6%
DE	145	118	161	172	16%
AU/Switherland	13	13	16	17	24%
Eastern Europe	136	98	131	153	11%
Total	**1058**	**815**	**1015**	**1049**	**-1%**

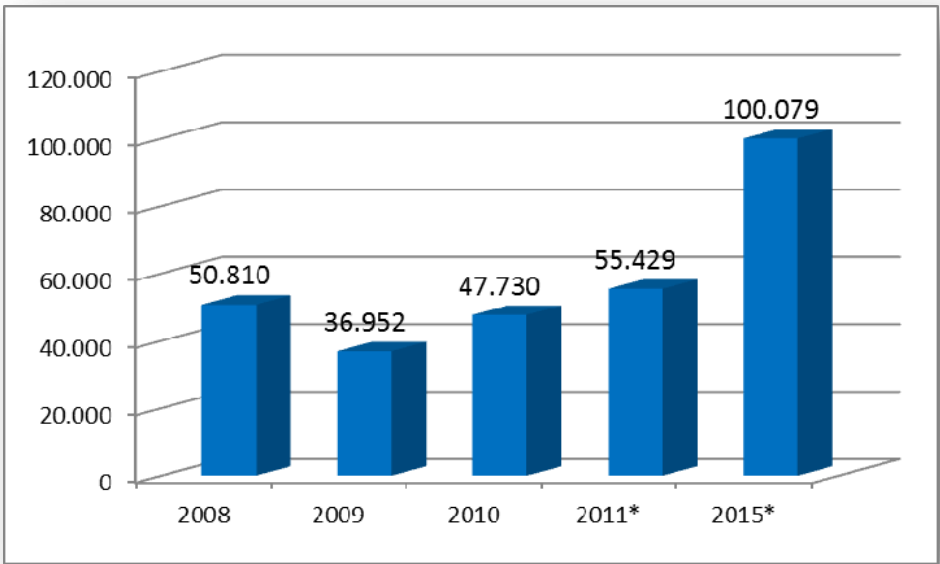
Source: AVK Composites market report 2011

3.3.2 The Carbon Fibre market

Carbon fibres are also used in rotor blades, because they present a series of advantages compared with glass fibres, such as superior strength and higher stiffness; the disadvantage is that they are more expensive.

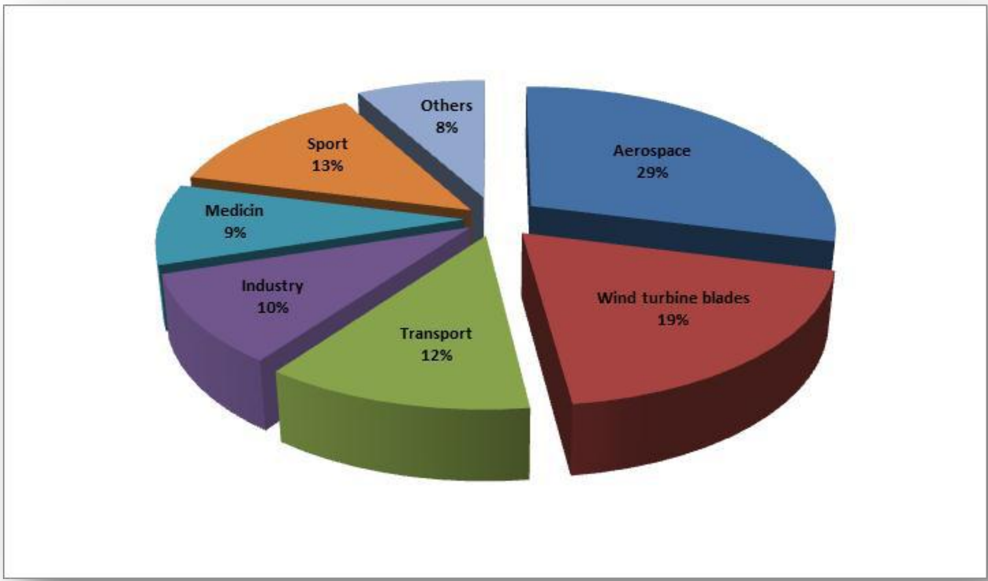
Figure 6 shows the global demand of CRP between 2008–2015; 50,810 tonnes of CRP were consumed in 2008, and the double is expected to be consumed by 2015. Figure 7 highlights that one of the main applications of the CRP is manufacturing wind turbine blades – 19% of total demand, 29% of the CRP applications are used by the aerospace industry. The 2 sectors represent half of the demand, the other half being used by transports, industry, medicine, sports and other.

Figure 6 Global demand for CRP 2008-2015



Source: AVK Composites market report 2011

Figure 7 Application of CRP with epoxy and or phenolic resins



Source: AVK Composites market report 2011

4 Recommendation and future work

Over the past 20 years the wind power industry has become an important user of composite materials. The lifetime of the first wind turbine installations is coming to an end and decommissioning is already taking place in the sector. Most of the wind turbine components are already directed to recycling, ensuring that the lifecycle of the technology is sustainable.

Up to now, the wind turbine blades were not included in the recyclable components. Due to the composites' use, recycling was not feasible either technologically or economically. Over the last years a number of solutions have been developed to recycle wind turbine blades. Developments in this field show the maturity of recycling companies to process wind turbine blades, turning the whole wind turbine into a recyclable machine.

In order to reach the point of maturity for the blade recycling industry some questions have to be answered in a European level:

- What is the necessary size of the facilities needed to accommodate the blade waste for the near future.
- What are the legislative measures that can stimulate the growth of this industry
- What is the market of the end-product (the after-recycling product)
- What is the necessary investment to build the necessary facilities

Answering these questions can be done:

- either by allocating time internally in the research group and producing a research note, available for comments to our members,
- or focusing on forming a consortium (which we already tried) and waiting to receive funding from an EU project