MASTER THESIS

Alternatives on afterlife use of amortized wind turbine blades in the Netherlands

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Written by: Iref Joeman

Supervisor: dr. M.J. Arentsen

Co-supervisor: dr. M.L. Franco Garcia

Company/Internship supervisor: A. Strijker (Pondera Consult B.V.)

University of Twente

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Abstract

Wind energy has been growing and evolving in the past decades. The size of the wind turbine blades have also been increasing and with a life expectancy of around 15-25 years depending on the wind class of the blades, there are little afterlife applications currently available for these blades. Recyclability of the blades is complicated due to the fact that it is made from composite materials, mostly epoxy and fiber glass. This creates an obstacle for the amortized blades, since disposing solid wastes in landfills have been restricted through legislation within the European Union (EU). With the current situation and the aim of many EU nations to reach their Sustainable Development Goals in 2030 and 2050, there is no doubt that these countries will have to find options to deal with the amortized blades. As the title states alternative methods on processing the end of life (EoL) wind turbine (W.T.) blades most likely applicable in the Netherlands and the EU or the globe will be discussed.

Four methods are discussed namely: pyrolysis, refurbishing, pavement application and landfilling of the amortized/EoL W.T. blades The most prominent options of dealing with the end-of-life rotor blades are: burning of the blades cut in pieces and use the heat to generate energy, pyrolysis and use the filler material in cement. Another option is to use the blade as an artificial reef which can be if given some time, beneficial in ecological terms. The artificial reef would function as a breeding place for a number of undersea life species. All the aforementioned options are viable solutions, but still face many obstacles due to lack of equipment and policies regulating and stimulating recycling the blades, transportation costs and maturity of applicable technology available at the moment.

In order to analyze the four methods a lifecycle assessment (LCA) has been conducted with the software GaBi (education version). This software was utilized in providing an indication on the environmental impacts each application or process has. A business case for recycling the EoL W.T. blades was also done in giving some insights on how financially feasible each process is. The LCA and business case were conducted with data obtained from the limited literature and assumptions. Pyrolysis and the pavement application based on the results have shown to be the most viable options in reducing the waste currently.

Around 20 percent of the blades in the Netherlands are refurbished and resold to buyers within and outside the EU. These blades also need to undergo a certification process before being sold to purchasing parties. Pyrolysis of the decommissioned blades is currently not applied in the Netherlands. Refiber, a company in Denmark was active in the pyrolysis process of the blades, but has been inactive for more than 10 years. The company claims that 5000 tons of amortized blades are required for the process to be operational. Extreme Eco solutions is currently active in the W.T. blades in pavement application within the Netherlands. Most blades after reaching their end of life are landfilled in the Netherlands due to its complexity in recycling them.

Foreword

This dissertation has been conducted for completing the Master in Environmental and Energy Management program at the University of Twente. A year has gone so fast and this amazing experience will definitely be cherished. I would like to thank my friends and family here in the Netherlands and in Suriname. My thanks also goes to my girlfriend, who supported me with everything during and before the graduation project. I would also want to thank my supervisors Mr. Arentsen, Miss Laura and Angelique for the advices and guidance. For the LCA (lifecycle assessment) I had much needed help from M. Toxopeus and Willem Haanstra. Without them the LCA would not have been possible. Last but not the least I would like to thank all the lecturers, office workers at Leeuwarden and fellow students for all their hard and the shared experiences during and outside the lectures. This thesis is an attempt and effort in finding viable direct solutions in tackling the issue with recycling end of life wind turbine blades in the Netherlands. My work does not guarantee a clear solution, but can be utilized in finding and developing current and new solutions in the future. The aim for this contribution is for it to function as one of the many stepping stones in finding solutions for the concerning issue. Hopefully this attempt will be successful and will inspire one of the readers to come with the innovations in improving the current and future situation of the amortized wind turbine blades. Finally, I end with the following self-written quote:

"Dare to find solutions against all odds, rather than give up and perish without giving a fight!"

Iref Joeman
30-08-2019

List of Abbreviation

AA	Acetic Acid
CFRP	Carbon Fiber Reinforced Polymer
EU	European Union
EoL	End of Life
ETS	Emission Trading Scheme
FP7	7th Framework Program
GFRP	Glass Fiber Reinforced Polymer
GHG	Greenhouse Gases
GW	Giga Watt
Kg	Kilogram
Km	Kilometer
kWh	kilo Watt hour
kt	kilo tons
LCA	Life Cycle Assessment
MW	Mega Watt
Nd	Neodymium
NdFeB	Neodymium Ferrium Boron
NPV	Net Present Value
NWEA	Nederlandse Windenergie Associatie
OSOW	Oversized and Overweight
R & D	Research & Development
REE	Rare Earth Elements
RoHS	Restricting the use of Hazardous Substances
SDE	Stimulering Duurzame Energie
SDG	Sustainable Development Goals

US	United States
WEEE	Waste Electrical & Electronic Equipment
WT	Wind Turbines

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I Introduction

1.1 Background

Wind energy is due to an abundance of wind power available, an effective alternative in replacing fossil fuels and reducing the CO2 emission in the Netherlands. The Netherlands aims to reduce its CO2 emission drastically and also attempts to be free of carbon emissions in 2050. Due to lack of sunlight and lack of area for a solar plant, wind energy has the edge over Photo Voltaic (PV) solar energy as PV technology is still being developed in order to improve its efficiency. There are a lot of windmills currently installed in the Netherlands. Most parts of the wind turbines are recyclable except for the blades. The afterlife usage of the blades is a cause of concern at the moment. Not many alternatives are available and with the prospected wind turbines to increase in the future within the country, an effective solution/ solutions should be created. Current available options will be explained and analyzed in this report and other alternative solutions will also be mentioned and worked out in detail. This work will not be limited to the available technology, but will also consider the social, economic and environmental impacts [1].

1.2 Problem statement

1.2.1 Problem statement

The EU-countries has many plans and policies set out with the aim to reach their sustainable development goals. Renewable sustainable energy is one of the aforementioned projected goals, in which wind energy is part of. Due to the fact of its high wind energy potential, the Netherlands has invested and implemented highly in wind turbines to ideal locations. In the last years wind mills have proven to be an effective source of energy in the Netherlands. Most parts of the wind mills are recyclable except for the blades. These blades have various lifetime expectancies due to weather conditions which may cause these to be damaged and replaced as a cause. Average life expectancy is around 20 years and there is no concrete plan on how to deal with the amortized blades. This thesis will focus on the afterlife use of the amortized windmills. Current and future options will be discussed and elaborated. Which sustainable management strategies can tackle the issue, which policies should be created and implemented for an effective result. This thesis will also look at options how the solutions can be integrated within a framework.

1.3 Research objectives

The objective of this research is to explore ways on how recycling the end of life blades can be of economic value without harming the environment. A stakeholder analysis will also be conducted. End-of-life alternatives which currently may have an effective impact on dealing with the issue will be discussed. Based on these findings a choice will be made which options can be implemented in short term and which steps should be taken in regards to policies and the roles and responsibilities of the stakeholders.

1.3.1 Research questions

What is the technical and environmental state of the art of the afterlife application of amortized wind turbine blades in Europe and which options are suggested in the academic literature and by experts in the field to improve the economic and environmental performance of the afterlife application?

With reference to the introduction the main research question can be described as follows:

1.3.2 Sub questions

Please find below the sub questions linked to the main question described above.

1. What is the current Technical state of the art of the afterlife application of amortized wind turbine blades in Europe?
2. What is the environmental impact of the current afterlife applications?
3. Which environmentally benign alternative technological options are suggested in literature and by experts?
4. What is the expected environmental and economic improvement compared to the current afterlife application of amortized wind turbine blades?

1.4 Wind Energy in general

Wind energy has made several progressions in becoming more efficient in the last decades (Figure 3). The blades are much lighter and much more energy. With all the aforementioned attributes of the blades, come some challenges which needs to be asserted. Lighter and much efficient blades have been growing rapidly in recent years, which make it difficult to install and decommission after reaching its lifecycle. Another crucial problem with the blades is that the composite materials from which the blades are manufactured are difficult to recycle. This has put the wind energy application in somewhat of an imbalances scale given below in Figure 1.

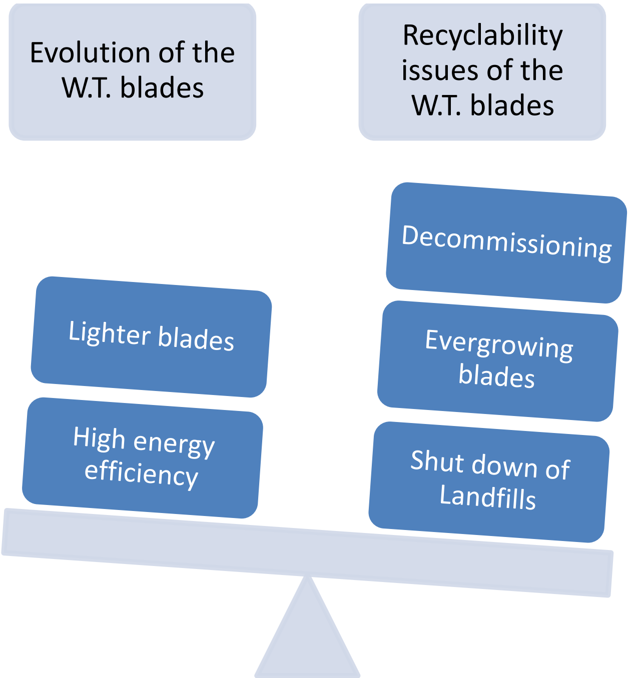


Figure 1 Pros and cons of wind turbine weighed on a scale

Since landfills are phasing out within the European Union (EU) and reaching the Paris agreement in which CO2 emission targets have been set by a number of countries, the necessity of tackling the issue on recycling or reducing the waste stream of amortized wind turbine blades has emerged. These occurrences have led to the creation of circular economy in which recycling or reusing of waste streams is stimulated. In Figure 2 you can see the three main pillars for recycling the wind turbine blades. The methods in tackling the issue will be elaborated in the following sections of the report.

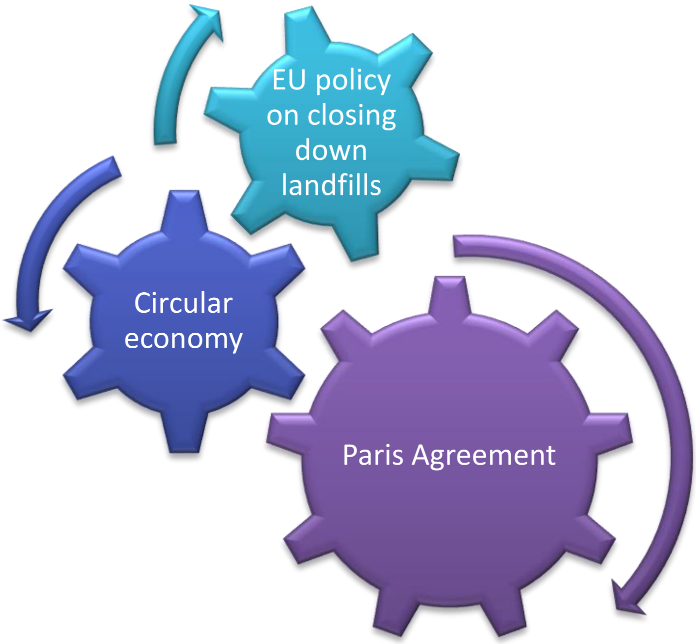


Figure 2 Three main pillars for recycling W.T. blades

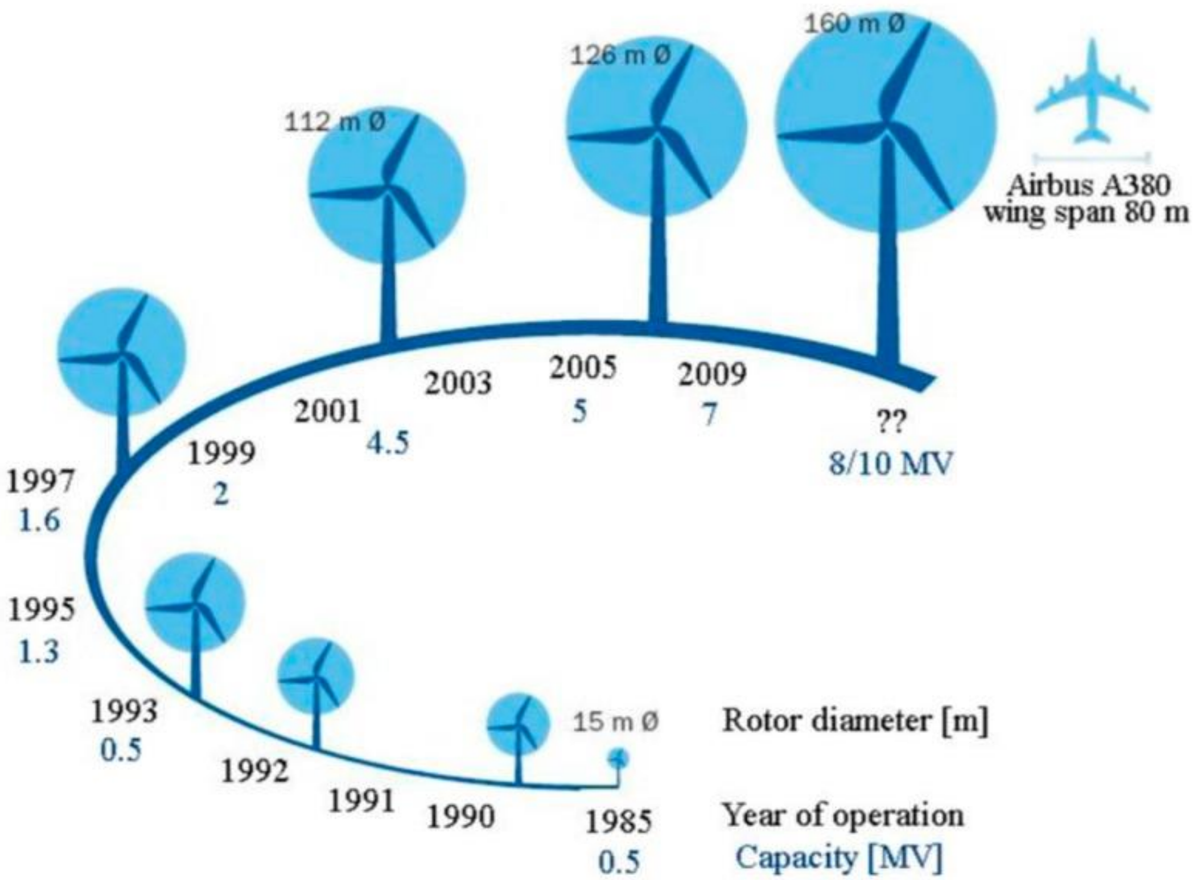


Figure 3 Development of larger and more efficient blades

1.5 Policies and materials used in the wind turbine blades

1.5.1 Evolution of policies within the EU

Hydroelectric and wind energy became the main sources of renewable energy in the world in 2016. Although wind energy has had a steeper growth compared to hydroelectric energy. The global cumulative installed wind power capacity, increased on average by 15% onshore and 33% offshore yearly between 2010 and 2017. Offshore wind power has the higher increasing rate due to its higher producing power capacity.

Policies on improving the solid waste management in Europe have undergone many alterations as is given below in Figure 4.

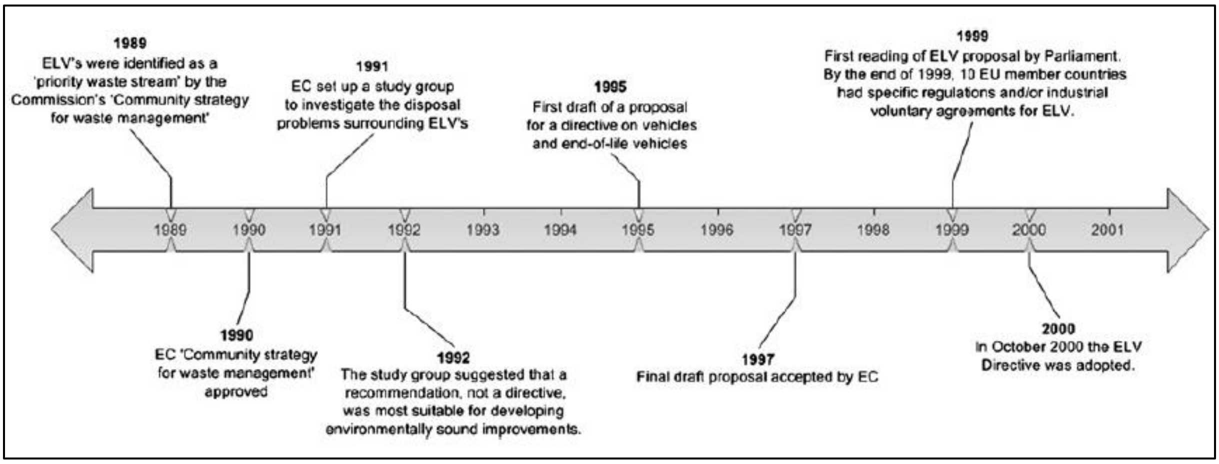


Figure 4 String and changes of policies in favor of tackling climate change issues throughout the years [2]

The status quo on Climate change, Greenhouse gases and Energy security has a trend of growing political concern on a global scale, consequently leading to environmental legislation and the development of renewable energy technologies.

Wind turbine blades are a crucial part of the system due to their aerodynamics, weight and structural properties in capturing kinetic energy. The development of the blades in recent years have, been designed in such a way improving their material properties, performance and economy. They are also designed to resist certain conditions like extreme gusts causing high structural loads. Testing of the W.T. blades is done on static extreme load matching to a 50 year gust wind and a cyclic loading similar to a 20 year fatigue life [2].

Recycling wind turbine blades is challenging as a consequence of the following factors:

- The blades consists of a complex material composition of fibers, namely Polymer matrix and fillers
- The cross-linked character of the thermoset material makes it difficult or impossible to remold the material
- The wind turbine blades during their 20 year lifetime are continuously exposed to numerous hostile conditions such as extreme temperatures, humidity, rain, hail impact, snow, ice, U.V.-radiation, lightning and salinity

- After their life-cycle of 20 years, most of the blades cannot be refurbished and reused due to damage of the material and or erosion of the edges of the blades
- The size of the blades, especially the larger ones are a cause of concern in terms of logistical problems like dismantling, transportation and cutting [2] & [3].

In 2008 the European Union (EU) climate change and energy package was enacted with the aim in reducing greenhouse gas emissions and minimizing the dependence on energy sources coming outside the EU. The adopted package by the EU contains these instruments:

I. **EU Emissions Trading Scheme (EU TS).**
This is a system that keeps a tab on the quantity of industrial greenhouse gases which can be emitted. Emissions allowances are provided for the companies, which can be traded among each other. The climate change and energy package consists an amendment to Directive 2003/87/EC in order to improve and broaden the Emission Trading Scheme.

II. **Greenhouse gas (GHG) emissions target.**
An EU commitment was adopted in which member state have agreed upon reducing greenhouse gas emissions by a target level 20% in 2020 compared to the GHG levels in 1990.

III. **Renewable energy sources (RES) 2020 target.**
A target level of generating 20% of energy from renewable sources in 2020 was set by the EU. Target levels were decided per member state.

1.5.1.1 Recycling economics

A comparative analysis can be utilized in determining the economic viability of recycling the WT blades. Pre the installation phase of any WT project, a decommissioning plan is created, mapping out potential costs and time roster for disassembling and disposing wind turbines and co related infrastructure after their life cycle. Evaluation for future decommissioning costs is difficult because of the following factors:

- Salvaging or maintaining value of the material—Fluctuation of market value of materials are unpredictable
- Costs for recycling—Recycling methods are still being developed, which will reduce the cost of the applied technology in the near future. The extent of this occurrence is for the moment uncertain
- Costs for disposal—A tax on the disposal of the waste is included. The tax on landfill disposal (Directive, 1999/31/EC) can be charged by weight and type of material.

Aforementioned, the EU landfill directive in 1999 aims to progressively reduce levels of biodegradable waste ending up on landfill and banning landfilling of certain hazardous wastes like liquid chemical waste, wastes from clinics and hospitals and used tires. Every EU country has interpreted and applied the directive in their own way. Germany was the frontrunner back in 2005 when it banned untreated municipal wastes on landfills. This led to materials with a high content of organic material, like wind turbine blades containing 30% organic material to be allocated for alternative end of life applications. Figure 5 indicates an overview of the waste stream of materials associated with Wind Turbines and the end of life processes available for those materials [2].

The Netherlands also has a ban on municipal and industrial wastes ending up at landfills. Despite this ban, most end of life non-revisable wind turbine blades are landfilled without fine or payment. Main reason for this is that the central government and the municipalities acknowledge the difficulties for recycling or processing the blades [2].

1.5.2 Material stream and growth on a global scale

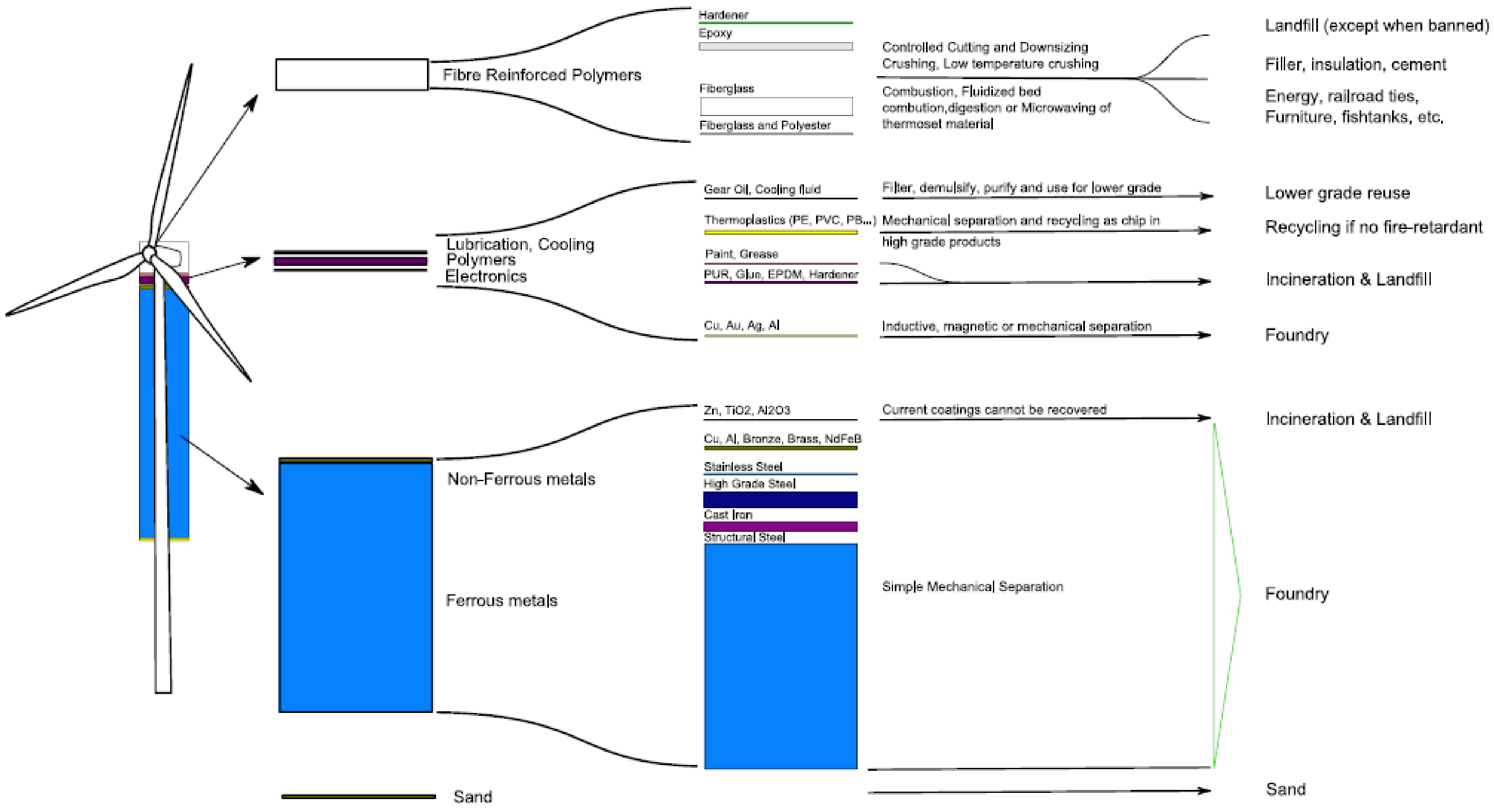
1.5.2.1 Material of the blade

The WT blades are manufactured from composite materials consisting of more than one bonded material, each material containing different structural properties. One of such materials, known as the reinforcing phase is implanted within the other material in matrix phase. Once the composite is designed and manufactured adequately, the reinforcement strength is accumulated with the matrix’s toughness resulting in an accumulation of viable properties which not available in other conventional material. The possibility of gaining a high ratio of stiffness to weight is one of the important advantages of using composite materials. Composites applied for engineering applications are usually advanced fiber or laminated composites like fiberglass, glass epoxy, graphite epoxy and boron epoxy. These materials are not easily shaped than isotropic materials like iron or steel. Therefore special consideration must be made in establishing the properties and orientations of the different layers considering each layer probably having various orthotropic material properties [4].

A wide range of WT blades are manufactured from GFRP with either polyester or epoxy resin. Other designs or types apply wood-epoxy or alternate materials. Smaller blades are manufactured from steel or aluminum, but heavier considering the scale and weight length ratio [4].

The lighter the blades become, the more efficient the use of material and the generating energy capacity becomes while also reducing the costs to produce them. Carbon fiber based composites are usually applied for much longer blades in order to lower the weight of the blades (from 20-28 Tons at a length of 61.5m). CRFP is also easier to mold compared to GFRP and also has a superior stiffness. Although the application of CRFP demands entailing accuracy, it also has higher production costs [4].

Figure 5 Stream of materials linked to Wind Turbines and the available processes for each material [2]



The average recyclability of all the wind turbine components is estimated to be 80% by mass, without the foundations. Although the blades, foundations and waste stream from components contribute to the largest number of wastes which end up on landfills. Wind turbines mostly contain the following materials like steel, aluminum, glass fiber, polyester, carbon fiber and epoxy. Most materials like the metals are easily recycled, but that isn't the case for the glass and carbon fiber materials. Vestas WT blades for example are mainly made from Carbon fiber, Glass fiber, epoxy resin and polyurethane (PU) adhesive which makes it difficult to recycle the blades [2].

1.5.2.3 Outline markets for glass fibers

Many factors come into play concerning the recyclability of a material like glass fiber, but more importantly the availability of a market for the recyclate or material should also be carefully considered. Companies which take responsibility for each of their own waste management, undergo difficulties when it comes to the economic scale and costs for transportation involving waste management. For that reason a reliable feedstock and demand is necessary, which can be achieved by creating cooperative programs. The main focus will be on recycled carbon and fiber glass materials in which the market for these materials will be investigated [2].

1.5.2.4 Carbon and Glass fibers [2]

Reinforced fiber composites are light in weight, have good strength and are chemically inert, which are the reasons why these materials are largely applied in a great number of applications. This is especially applied within the aerospace industry, the Boeing 787 Dreamliner for example is made of 50% composite material (by weight). The production of glass fiber has been increasing in the last years. A total of 1 million tons of GFRP was produced in Europe back in 2010, which was an increase by 25% compared to a year before in 2009. The increasing trend led to research of significance in finding methods for recycling the GFRP materials. It should be mentioned that the cost of recycling processes and an insufficient market for the recyclate, can be acknowledged as the important shortfalls in implementing the recycling at the moment. If recycling becomes necessary, through legislation for example, it would still require some time and effort in developing a decent market and recycling methods. Glass fiber composites are produced on a large scale throughout the globe due to its wide applications in Aerospace and wind energy. Albeit widely produced, there are little to no financial instruments in place, supporting GFRP composites to be recycled. When Carbon Fiber first into the market back in the late sixties, it was priced at £200/kg. The price for CFRP was £15-40/kg in 1996 and in 2009 it dropped to £13/kg. The price for GFRP is estimated to be £1-2/kg, making it the much cheaper option of the two fiber materials [2].

GFRP and CFRP are thermoset based composite materials which represent around 80 % of the market of reinforced polymer materials. Thermosets have the following advantages:

- Possibility of low room temperature curing
- Lower viscosity which facilitates infusion, which allows high processing speed

In first instance, polyester resins were used in wind turbine blades. Epoxy resin gradually replaced polyester as the blades got bigger and are currently used widely in wind turbine blades as polymer matrices. Recent studies have shown that companies like the Swiss DSM Composite Resins have argued for the return of unsaturated polyester resins, claiming that the newly developed polyesters meet all the strength and durability requirements for large wind blades. It should be noted, that for further development of matrix materials with a fast curing time at lower temperatures is crucial within field of research.

The graphs and tables which follow show data for Carbon Fiber Reinforced Polymer (CRFP). Because of the many similarities of applications and properties between CRFP and GRFP, the same trends/predictions can be made for GRFP. It should be noted that GRFP is mostly used in wind turbine blades due to it being the cheaper option, although CRFP is better qua endurance and performance.

The following data was collected for a report which was available at the time 2014. With this data a trend line graph was created as seen in Figure 6. In the graph a linear increase can be seen from the year 2010 to 2017. Before 2010 no GRFP or CRFP was used in making the W.T. blades, which is the reason why the graph starts after 2010. Data of the last three years (2015-2017) have been calculated with the following equation:

Equation 1: $GR,i = \frac{(P,i-P,i-1)}{P,i-1} \times 100$ **[5]**

GR is the growth rate during year *i*, indicated in percentages. *P* is the installed capacity during year *i*, indicated in MW. With Equation 1 "*the average growth rate of the cumulative installed capacity and the standard deviation of the values"* over a period of 7 years are calculated [5]. The calculated average growth rate is equal to 15.4 ± 3.6% annually. Yielding to three scenarios and these are:

1. Minimum scenario of installed wind power growth rate
2. Average scenario of installed wind power growth rate
3. Maximum scenario of installed wind power growth rate

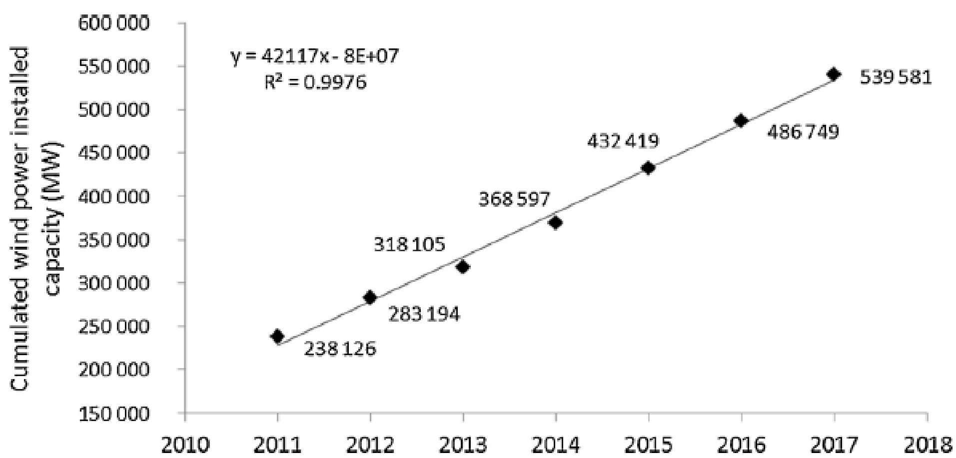


Figure 6 Accumulation of installed wind power capacity globally from 2010 till 2014 [2]

	Onshore wind turbine > 2 MW (%)	Offshore wind turbine > 2 MW (%)
Europe	18.3 %	99.0 %
Asia	14.9 %	98.6 %
North America	26.3 %	99.7 %
Latin America	59.2 %	99.7 %
Oceania	59.2 %	100 %
Africa & Middle East	33.7 %	100 %
World	19.2 %	99.0 %

Table 1 Installed global numbers of onshore and offshore wind turbines in 2014 [2]

	Growth rate (%)					
	2017	2018	2019	2020	2021	2022
Europe	10 %	7 %	8 %	7 %	7 %	7 %
Asia	12 %	10 %	11 %	11 %	10 %	9 %
North America	8 %	9 %	9 %	10 %	8 %	7 %
Latin America	17 %	19 %	15 %	11 %	10 %	13 %
Oceania	5 %	16 %	10 %	21 %	13 %	10 %
Africa & Middle East	16 %	41 %	17 %	23 %	21 %	23 %
World	11 %	10 %	10 %	10 %	10 %	10 %

Table 2 Projected growth rate of wind turbines in the world from 2017-2022 [2]

The application of wind energy has been rising in recent years, especially the offshore wind farms have been increasing in number. Table 1shows a percentage of in use onshore and offshore windfarms in world back in 2014.

Due to its successful application and improvements of the blades (length and efficiency) the current number of wind turbines in use is expected to rise within the coming years. This is shown in Table 2 in which the estimated growth rate is also provided. Table 2 also provides the installed capacity of wind energy in the world and the estimated projections in the coming years.

The graph shown in Table 3 indicates the amount of each continent per period (the years 2017, 2020 and 2025 respectively), given in the unit tons considering the 3 scenarios explained earlier. Based on the given equation and other factors like the 3 scenarios, predictions can be made for the years/period given in Figure 7. The predictions represent a rising trend of CRFP being utilized when all continents are bundled in one staff.

Estimated cumulative installed wind power capacity (MW)								
	2010	2017	2020*			2025*		
Scenario			1	2	3	1	2	3
Europe	86,800	178,100	233,900	257,300	282,800	381,300	491,300	632,400
Asia	61,200	228,500	327,400	360,000	395,800	587,900	757,600	975,200
North America	44,900	105,300	145,500	160,000	175,900	240,400	309,800	398,800
Latin America	1,500	17,900	29,000	31,900	35,100	59,900	77,200	99,300
Oceania	2,500	5,200	8,500	9,300	10,200	16,100	20,700	26,700
Africa & Middle East	1,100	4,500	9,700	10,700	11,800	31,400	40,500	52,100
World	198,000	539,500	754,000	829,200	911,600	1,317,000	1,697,100	2,184,500

Table 3 Estimated cumulative installed power capacity in MW for each continental regions applying the 3 scenarios [5]

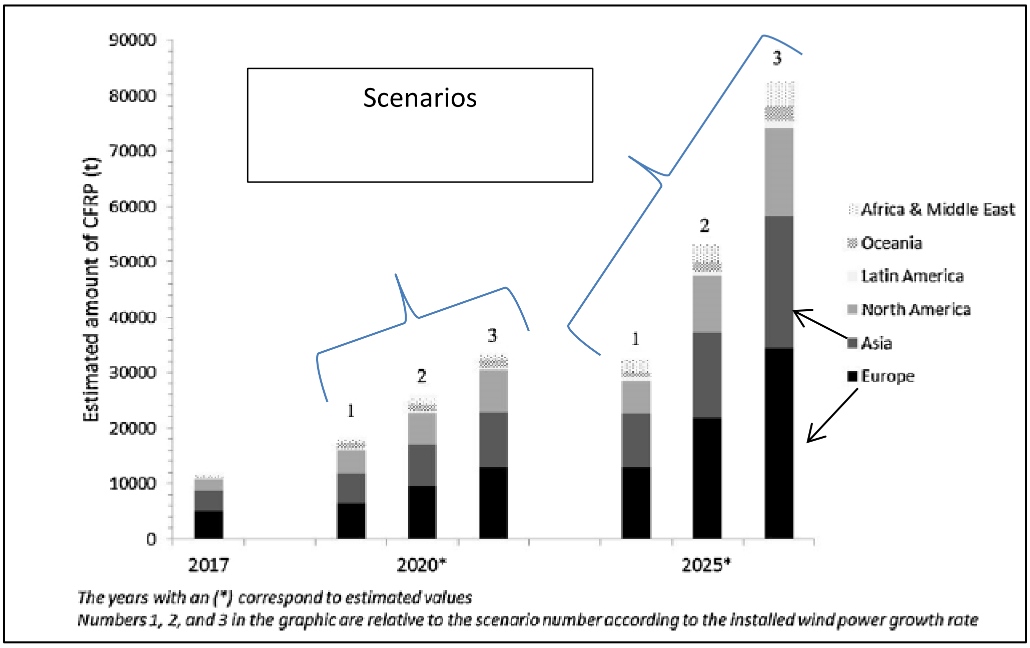


Figure 7 Approximated quantity of CRFP by geographical sections indicated in 2017, 2020 and 2025 respectively [5]

As Figure 8 shows that 9190 tons of CFRP went into the technosphere in the year 2017. This amount of CRFP will be added to the in use stock which represents 52214 tons accumulating to an “in use stock” of 61404 tons. This stock will then be subtracted by the quantity leaving the technosphere, representing the quantity of CRFP nearing its EoL, which zero in 2017. The flow shows zero in 2017, because no W.T. blade made from carbon fiber is dismantled yet according to Figure 8. The quantity of produced waste is set at 3584 tons, depending on which continent. We can see that Europe is the main producer of CRFP waste with 1408 tons, followed by Asia with 1038 tons. To conclude, the Oceanic region produces the least amount of CRFP waste [5].

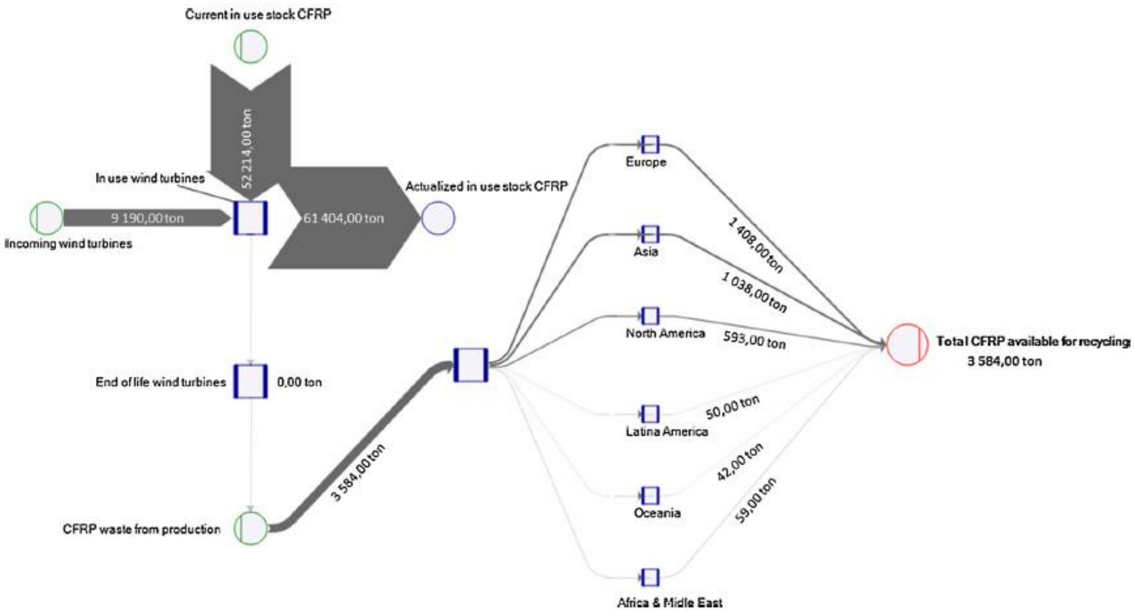


Figure 8 Schematic representation of the of CRFP flows in 2017, circulating and in stock through the technosphere [5]

The graphs in Figure 7 and Figure 9 and Equation 1 have been utilized to produce estimated amounts for periods till 2025 and 2050 respectively.

According to calculations by taking installed wind energy/power growth rates into consideration, a growth rate of 11.8% is expected in 2050. At which the wind energy sector will have generated around 482998 tons of CRFP waste globally. We see that Europe and Asia will produce the highest cumulative of CRFP waste of around 189751 and 148710 tons respectively by 2050. A second material flow analysis was done in approximating the quantity of CRFP which will be available by 2050. As indicated in Figure 10 and Figure 11, the "in-use stock" is exponentially rising from 2017 till 2050, representing the 2050 circulation over the technosphere [5].

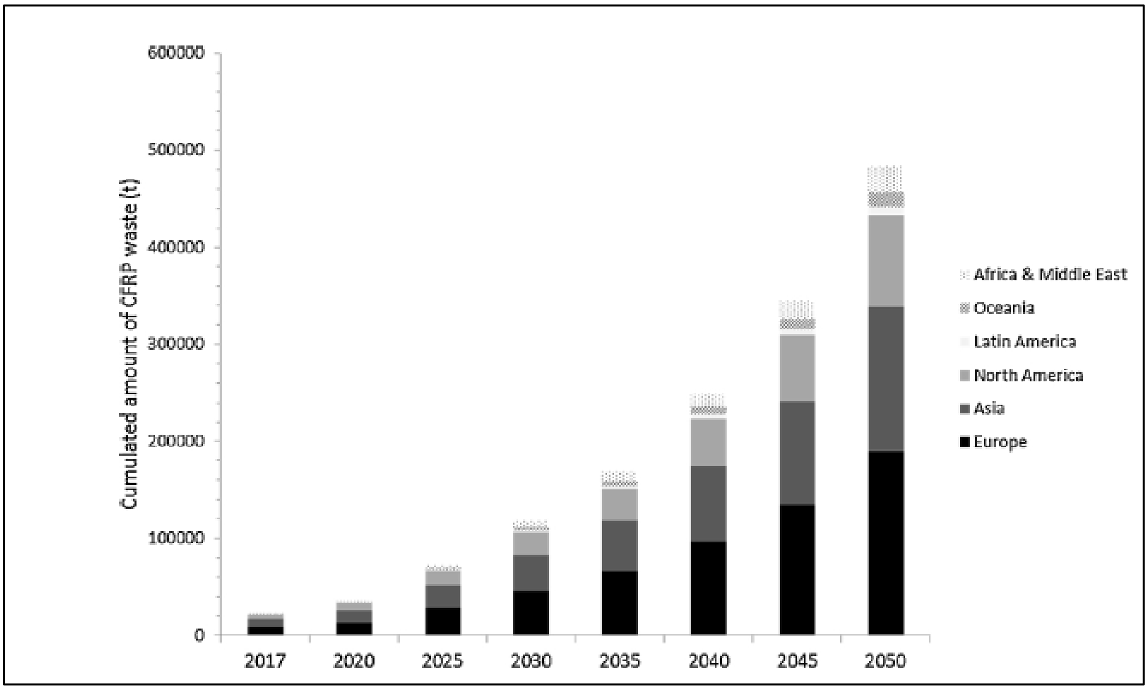


Figure 9 Changes in the quantity of the overall waste generated from the wind energy sector shown for each region, in periods of 5 years until 2050 [5]

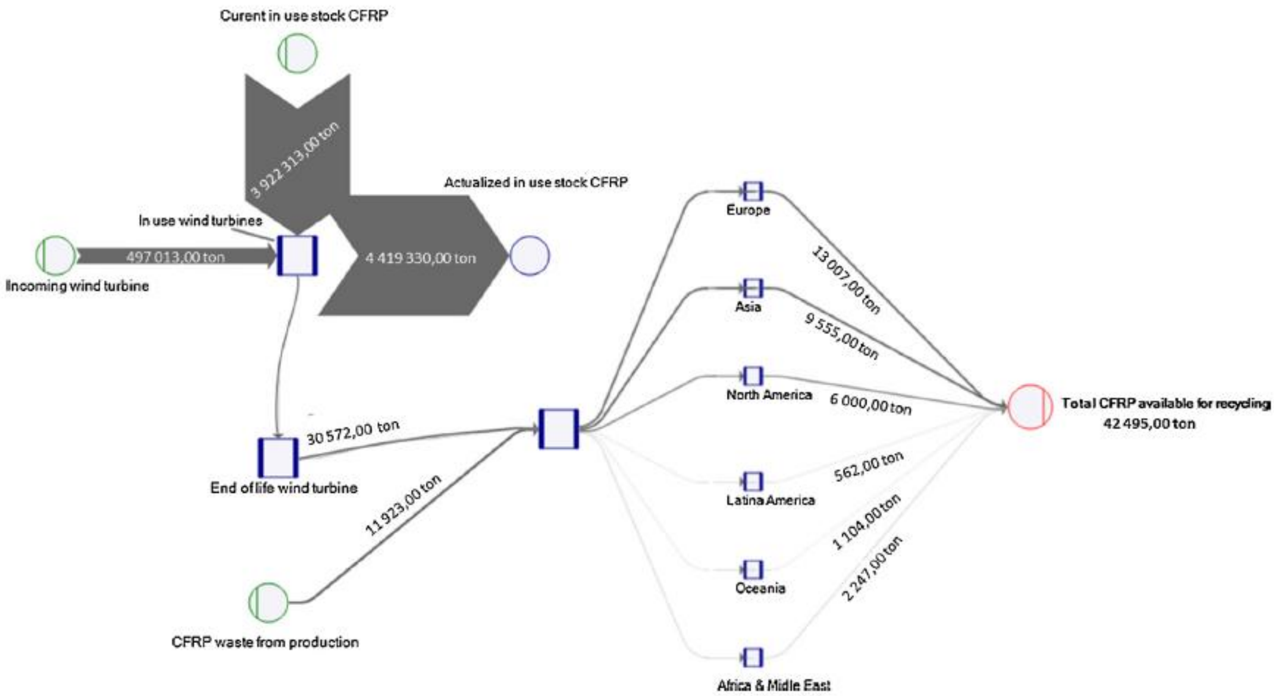


Figure 10 Indication of the CRFP flow in 2050, circulating and in stock through the technosphere [5]

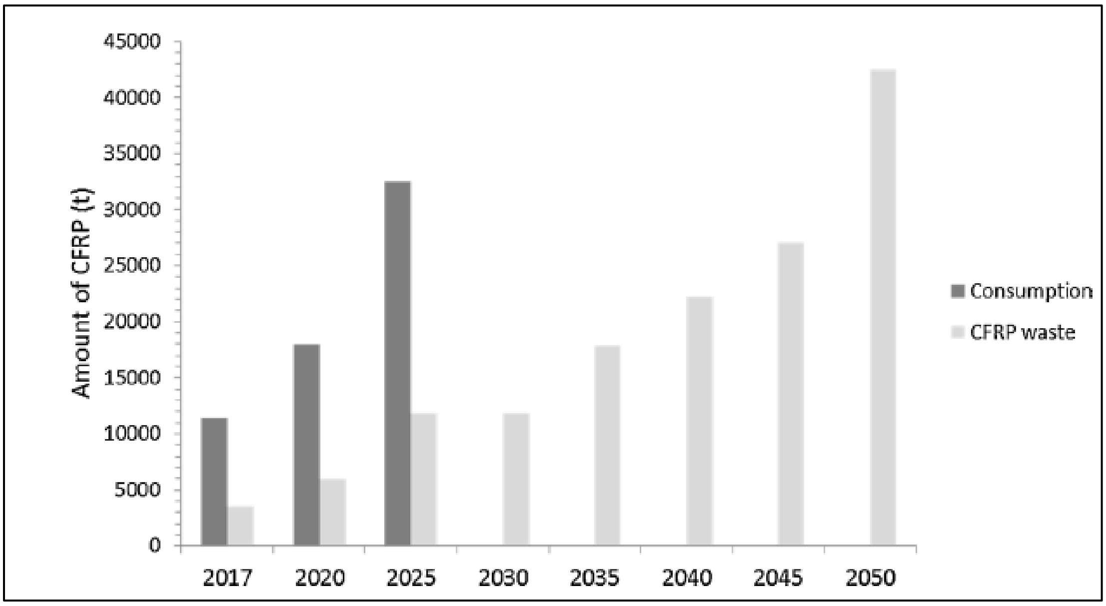


Figure 11 Shift in consumption of CRFP in the world in the wind energy sector compared to the amount of CRFP produced as waste, indicated in periods of 5 years until 2050 [5]

1.6 Discussion

The development of the wind turbine blades has made a lot of progress when the mass and efficiency is taken into consideration. All of the positive developments have led to an increase of wind turbines globally. A rise of wind turbines means also a rise in end of life W.T. blades which are difficult to recycle currently. To tackle the issue of the W.T. blades policies needs to be created to promote recycling. Throughout the years landfills have gradually been closed down in Europe and this brings out a challenge on finding a viable solution to reduce the number of Glass fiber W.T. blades. Glass reinforced polymer and Carbon reinforced polymer are widely used for W.T. blades due to their material and aerodynamic properties. There is a market available for these materials and this can be taken as a stimulus in finding a way to recover the GRFP and CRFP materials in the blades.

Some estimated projections were made on how much fiber material will be in the market in the future. Due to GRFP and CRFP being similar within the aerospace and wind energy sector, the produced tables, calculations and graphs of CRFP was utilized in giving an idea of how much of the W.T. blades can be expected as waste. From the numbers provided in graphs and tables, we can conclude that there will definitely be an increase of EoL wind turbine blades in the future.

II Current Technical state of the art afterlife application of amortized wind turbine blades

2.1 Wind turbines in the Netherlands

Post a long period of catching up, the energy transition within the Netherlands has managed to overhaul the gap in recent years. After the 2013 Energy Agreement, the evident Paris Agreement on climate change was signed in 2015. The heated debate on the Groningen natural gas dossier and shutting down coal-fired and nuclear power plants has put more importance on the transition to a safe and CO2-neutral society. The Netherlands has an installed wind energy capacity of over 3500 MW installed in 2016 which is sufficient in supplying 2.3 million households. According to NWEA, 7.4 % of the planned 16 % renewable energy (potential wind energy) has been realized. Wind energy is a crucial component of the Energy Agreement [6].

The number of wind turbines in the Netherlands which are still in full use at the moment is around 2316 [7]. This amounts to a total power capacity of around 4,43-4.5 GW see Figure 12 Installed wind power capacity in Europe .

Most wind turbines in the Netherlands are relatively new compared to Germany and Denmark in which many wind turbines have been completely decommissioned in recent time. This does not mean that the issue of End of life turbine blades is of no concern as some windfarms will need to be decommissioned, windfarms Zeewolde in which 118 wind turbines will need to be dismantled as early as 2026. Other windfarms will also follow after Zeewolde and this may create a situation in which a large amount of wind turbine blades need to be recycled or relocated [9]. Since landfilling is prohibited by law in the Netherlands, the only solution seems to point to incineration. This will not solve the problem since epoxy/ fiber glass material from which the blade is manufactured cannot be completely burnt leaving a huge sized slag behind. It is therefore a very challenging issue to deal with. Luckily EU-member countries like Germany and Denmark have been dealing with this issue and have also looked at and developed methods on solving this obstacle. These alternatives will be discussed in the next part.

Expected amount of wind turbine blades which will need to be processed after its lifecycle is about 140 kt (kilotons). Around 40% of the blades currently installed at windfarms will need to be processed/recycled [10].

Appendix VI shows the total installed, in use and decommissioned wind turbines in the Netherlands through a period of 20-35 years.

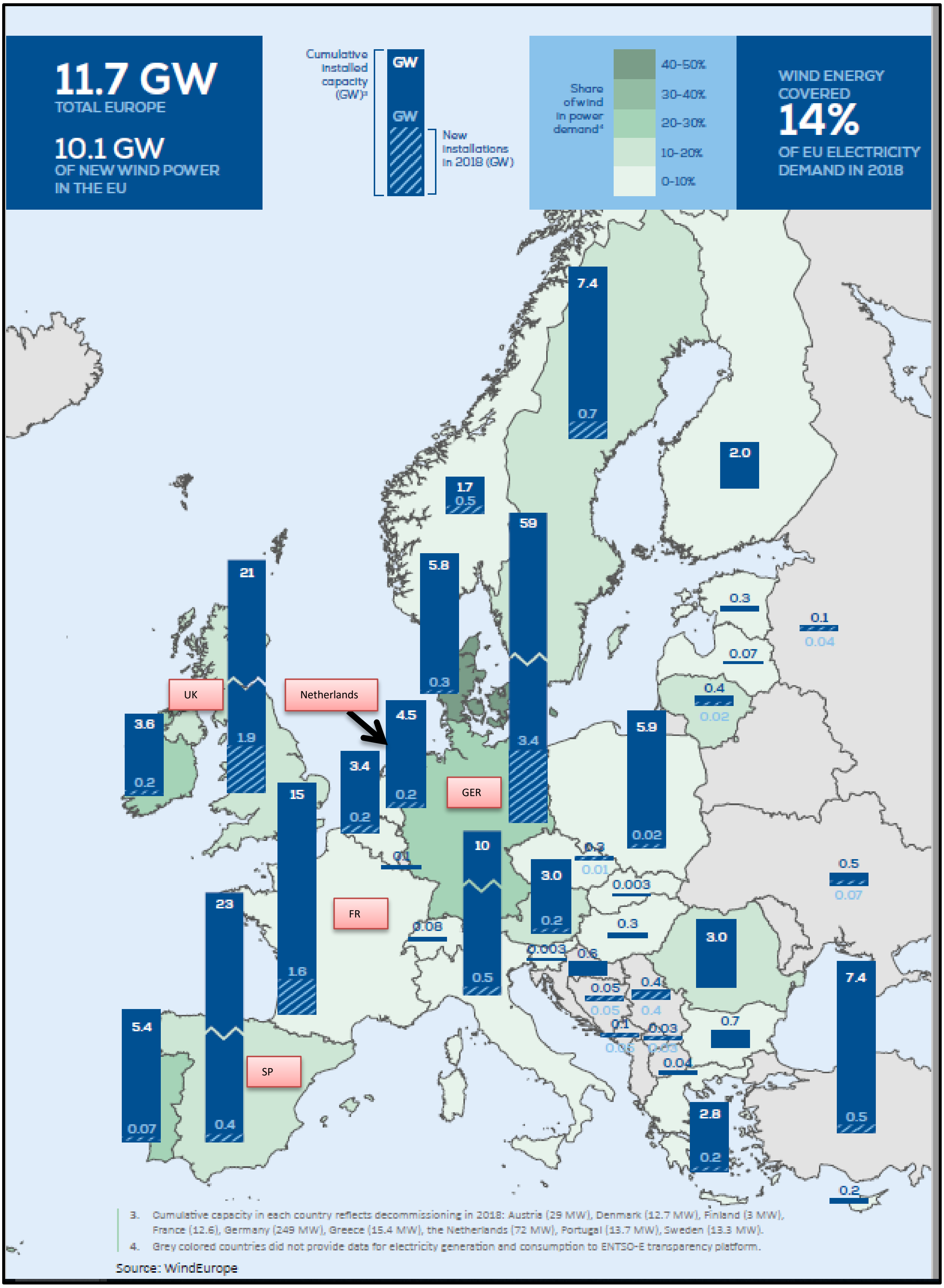


Figure 12 Installed wind power capacity in Europe [8]

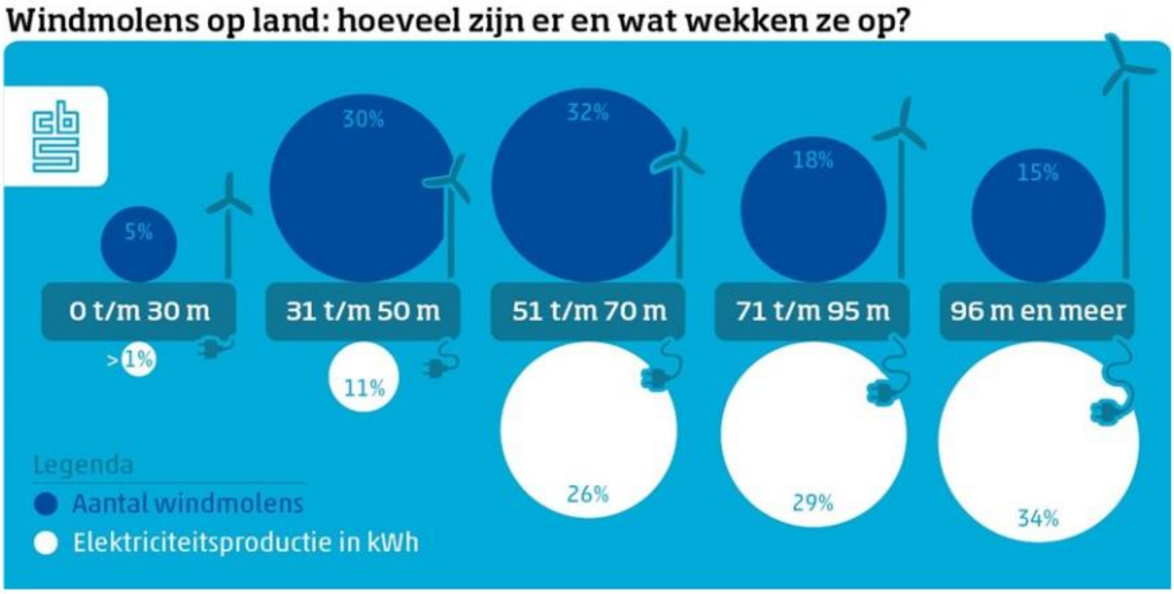


Figure 13 Installed onshore wind turbines in the Netherlands categorized in height and the produced capacity [11]

2.2 Current alternatives for the afterlife use of wind turbine blades

Wind energy application will increase in the coming years based on statistical data provided from many sources. It is a great alternative solution in replacing fossil fuels, but despite having many positive aspects there are some concerns with the blades. The blades are made from composite material, which is difficult to recycle. Most parts of the wind turbine can be recycled because of the materials they are made from can be recycled. Below, in Figure 15 there is a clear indication on the certainty/ uncertainty level of the activities and parts of the wind turbine within the recycling process. From organizing, dismantling to recycling electronics and cables and the other components of a whole wind turbine unit is given in Figure 14. The cables are manufactured from copper which can be recycled, but part of the cables remain underground because it can be used for another wind turbine installation and avoid damaging the ground when pulled out of the earth. Recycling the blades according the presented graph shows to be most uncertain which makes it quite challenging on finding viable solutions.

Component/material (% by weight)	Pre-stressed Concrete	Steel	Aluminum	Copper	Glass Reinforced Plastic
Rotor					
Hub		100			
Blades		5			95
Nacelle		80	3 - 4	14	1
Gearbox		98	2	2	
Generator		65		35	
Frame, Machinery, and Shell		85	9	4	3
Tower	2	98			

Figure 14 Components of a wind turbine and the used material given in percentages [12]

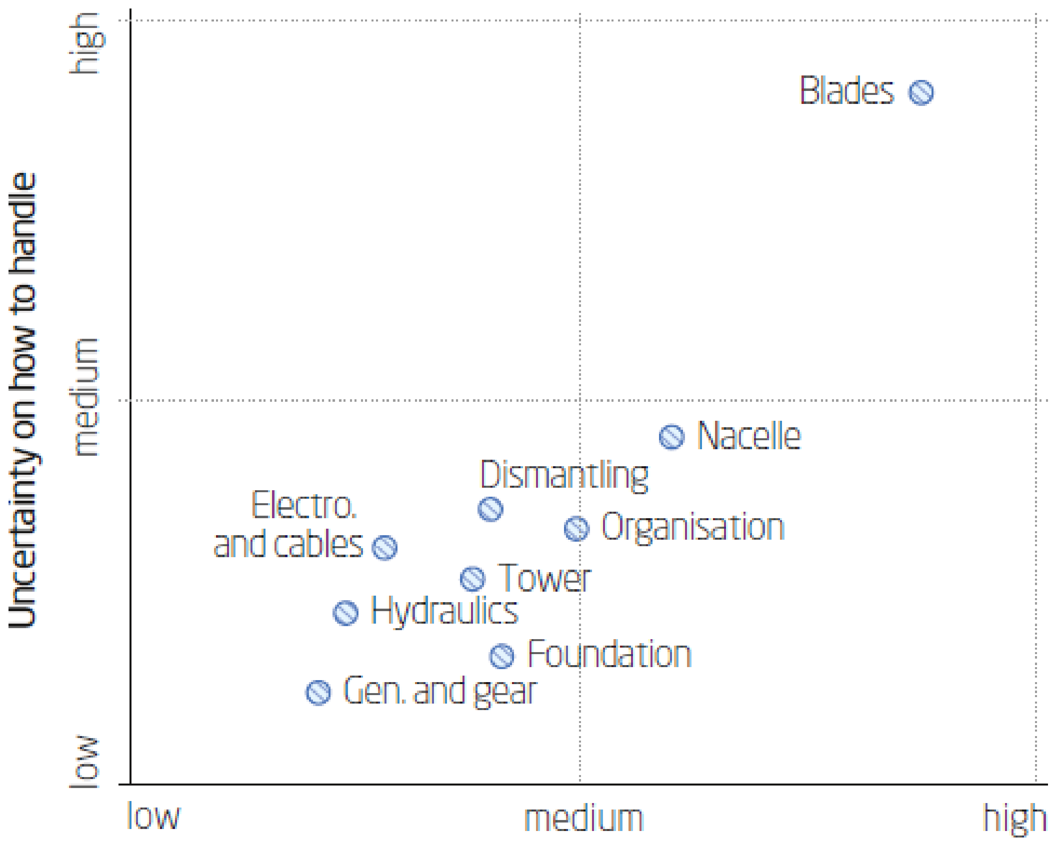


Figure 15 Uncertainty level on how to deal with the turbine blades [12]

Germany is one of the pioneering countries to prohibit solid waste to be disposed at landfills in 1990 (source). Other EU-nations have followed this example and with this policy the end-of-life blades need to be dealt with. Figure 16 gives an indication of the end-of-life options in preferential sequence. The first is prevention, preventing the occurrence as much as possible is the most preferred option and this can be achieved by using much more durable and improved material for the blades which would prevent or this matter delay the issue for some time. Second is the option of reuse, although the blades have a lifespan of 20-25 years they can be reused again if there are still in perfect condition. It is unlikely that these blades will be reused within the EU, but will be exported to developing countries due to economic reasons. Third option is recycling, although this is very difficult to achieve at the moment because epoxy/fiber glass is difficult to recycle. Replacing epoxy with recyclable material like thermoplastics would be a much viable solution. In fourth place we have the option to recover the some or most parts of the material which can be used in other application such as filler material in cement and aggregates in concrete. The latter option will be further discussed in this report. The last option is disposal at the landfill, but due to regulations prohibiting this in the EU, it is the least and most discouraged option.

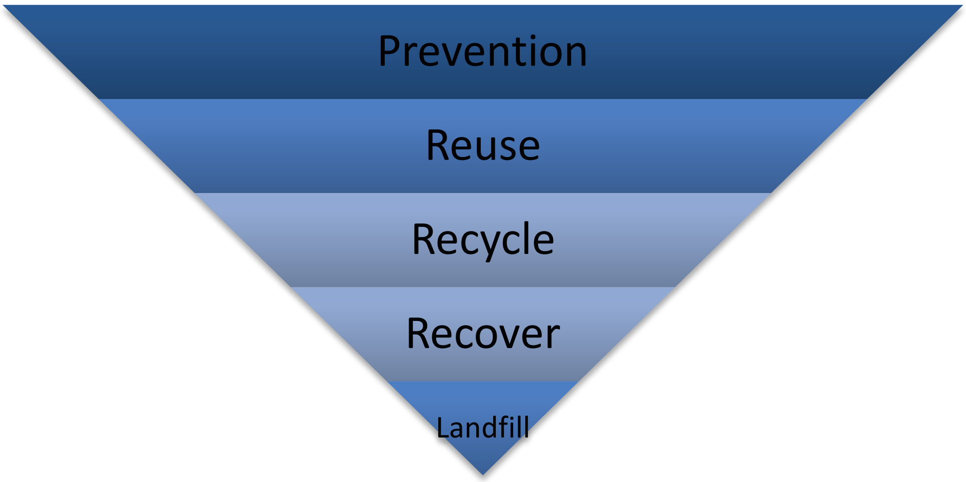


Figure 16 Preferential pyramid of EoL application of the blades

Despite the uncertainty level on how to deal with the amortized turbine blades there are fortunately some options to tackle the issue. Below in Figure 17 a flowchart of the whole process of recycling a wind turbine blade is given. Starting from dismantling the blades to the recycling options which are:

- Pyrolysis blade recycling process, a thermal recycling application in which the materials in the composite blade material extracted separately

- Blade composite aggregate replacing limestone in concrete, in which epoxy material is cut in ideal shapes and sizes with rough edges. The cut epoxy aggregate will substitute up to 25% of limestone aggregate in concrete [13]

- Refurbishing W.T. blades which are chosen through inspection and selected based on its repairability. In order to increase the number of refurbished blades in the future, the entire blade should be designed in such a manner making it easy to repair/ refurbish the blade. The design of the blades can be altered in such a matter making it easier to reverse engineer each component/ material. This would simplify recycling different parts and material in the wind turbine

- Lowest and most undesired end of life option of the blades is landfilling. This process involves cutting the blades in transportable sections either directly landfilling the cut blades or first incinerating and then landfilling the slag or residue material

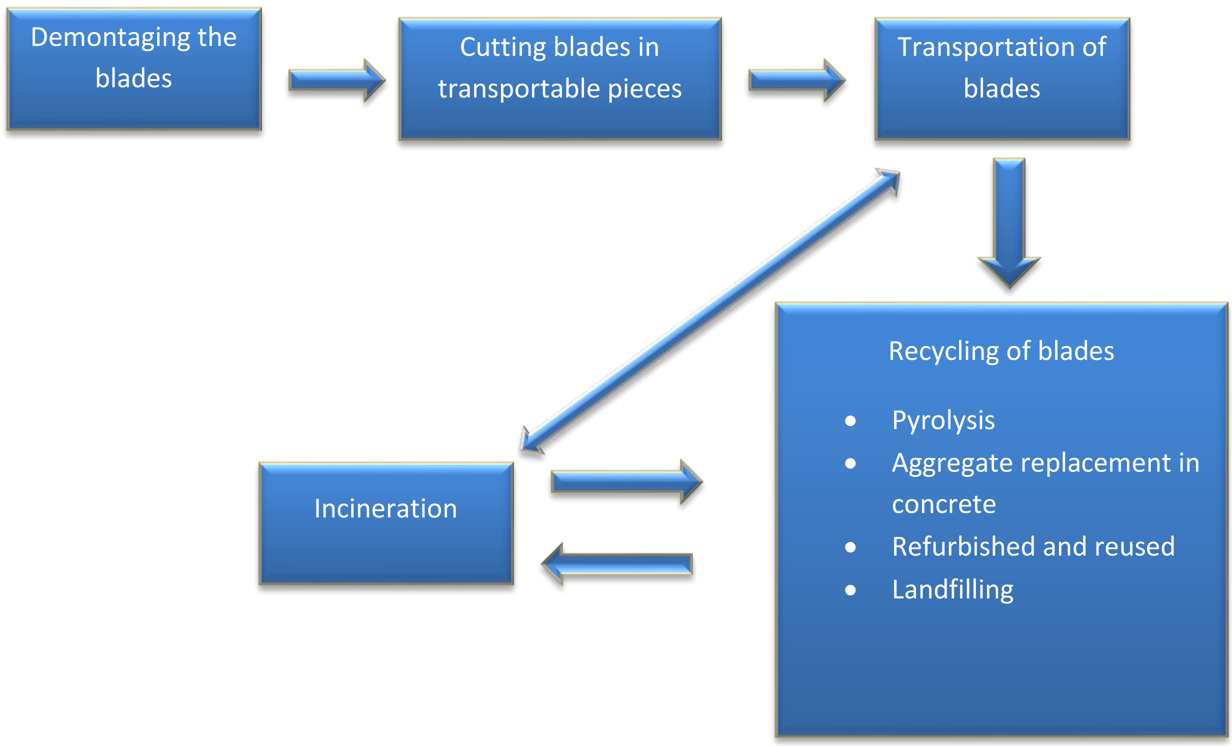


Figure 17 Recycling processes for wind turbine blades

The recycling processes will be discussed more in depth in the following section.

2.2.1 After-life destinations for non-reusable wind turbine blades in the Netherlands

Most of the amortized wind turbine blades in the Netherlands currently end up at landfills. There is no fee paid for the blades to be landfilled. The reason for this according to the waste management department of the Ministry of Rijkswaterstaat (minister of infrastructure in the Netherlands), is that there are no real applications in processing and or recycling the wind turbine blades [14].

2.2.2 Pyrolysis

Recycling in general has three main processes and these are:

a) Mechanical Recycling
b) Thermal Recycling
c) Chemical Recycling

All of the aforementioned processes and their subdivisions are shown in Figure 20. With pyrolysis process, recovery of energy is achieved similar to how gas is retrieved from combined heat and power (C.H.P.) plants utilized in district heating throughout the burning process. After the burning process, glass fiber residue remains which can be used as wool for insulating purposes. Short fibers can be used for reinforcing casting compounds, plastic items, high strengthening concrete and more. Refiber (Danish company, currently inactive) claims 3 metric tons of glass fiber composite can produce around 1 metric ton of pyrolysis oil.

Wind turbine blades are usually made of 50-60% GFRC (glass fiber reinforced composite). After incineration of the blades, a piece of slag consisting of GFRC material is left as slag. The slag cannot be used if household waste incinerated alongside the cut blades. This is not the case with pyrolysis which is a separation process.

Pyrolysis is a thermal recycling process given in Figure 18. The blade is inserted in the chamber which is heated up to 600 degrees Celsius. After this the residue material after the chamber will be separated into different materials: glass, metal, fillers, etc. The gas will be further heated in the after burner process to a temperature of 1100 degrees Celsius which will be used to generate energy [13].

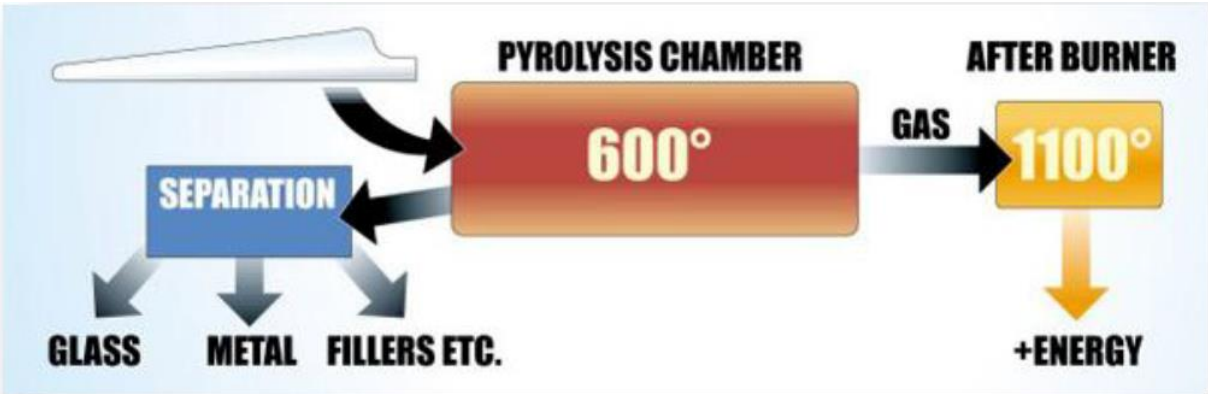


Figure 18 Pyrolysis recycling process [13]

Pyrolysis is the chemical putrefaction of a composite induced by temperatures above 250-300 ^{o}C. Putrefaction occurs due to chemical bonds containing limited thermal stability and can be fractured due to heat. Decomposition of this kind commonly leads to the formation of smaller molecules, even though the generated diffractions may occasionally interact, producing larger compounds compared to the initial molecules [15]. This process can negatively influence the mechanical properties of the recovered glass fibers due to the process occurring at temperatures higher than 450 ^{o}C [16].

2.2.2.1 Pyrolysis use in practice

Pyrolysis is used in the Netherlands, but not for recycling wind turbine blades. Companies like Empyro in Enschede uses Pyrolysis for processing biomass.

Refiber a wind turbine recycling company in Denmark which makes use of the pyrolysis process has not been operational for the past ten years. For the company to be operational and financially feasible, 5000 tons of wind turbine blades is needed [17].

2.2.2.2 Pyrolysis technical info

In the pyrolysis process heat is utilized in separating the composite material consisting of a polymer matrix. The process occurs in a nearly inert environment in which the process is anaerobic (no air), thus preventing combustion in which air pollution is minimal compared to incineration. The glass fiber component GFRC is nonflammable below temperatures of around 1000ºC, while it is the opposite for the resin. Putrefaction of the inflammable resin yields gases and pyrolysis oil during the burning process. The solid incombustible remains, existing of fibers and char can be used in cement, paint and other applications [10]. All of this is shown in Figure 19.

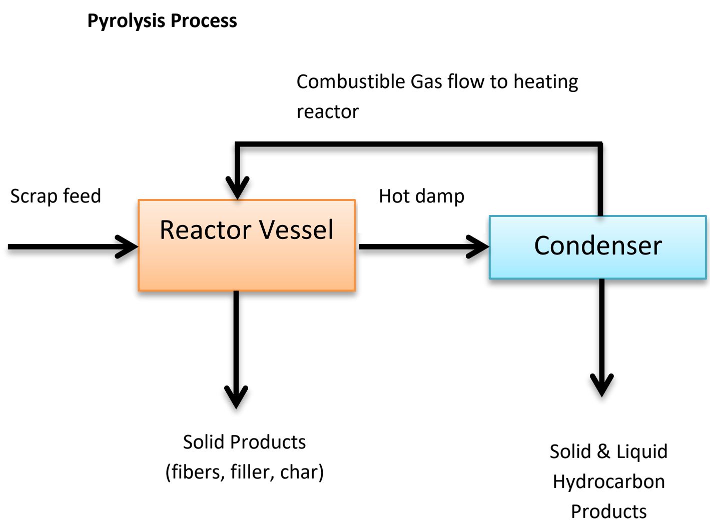
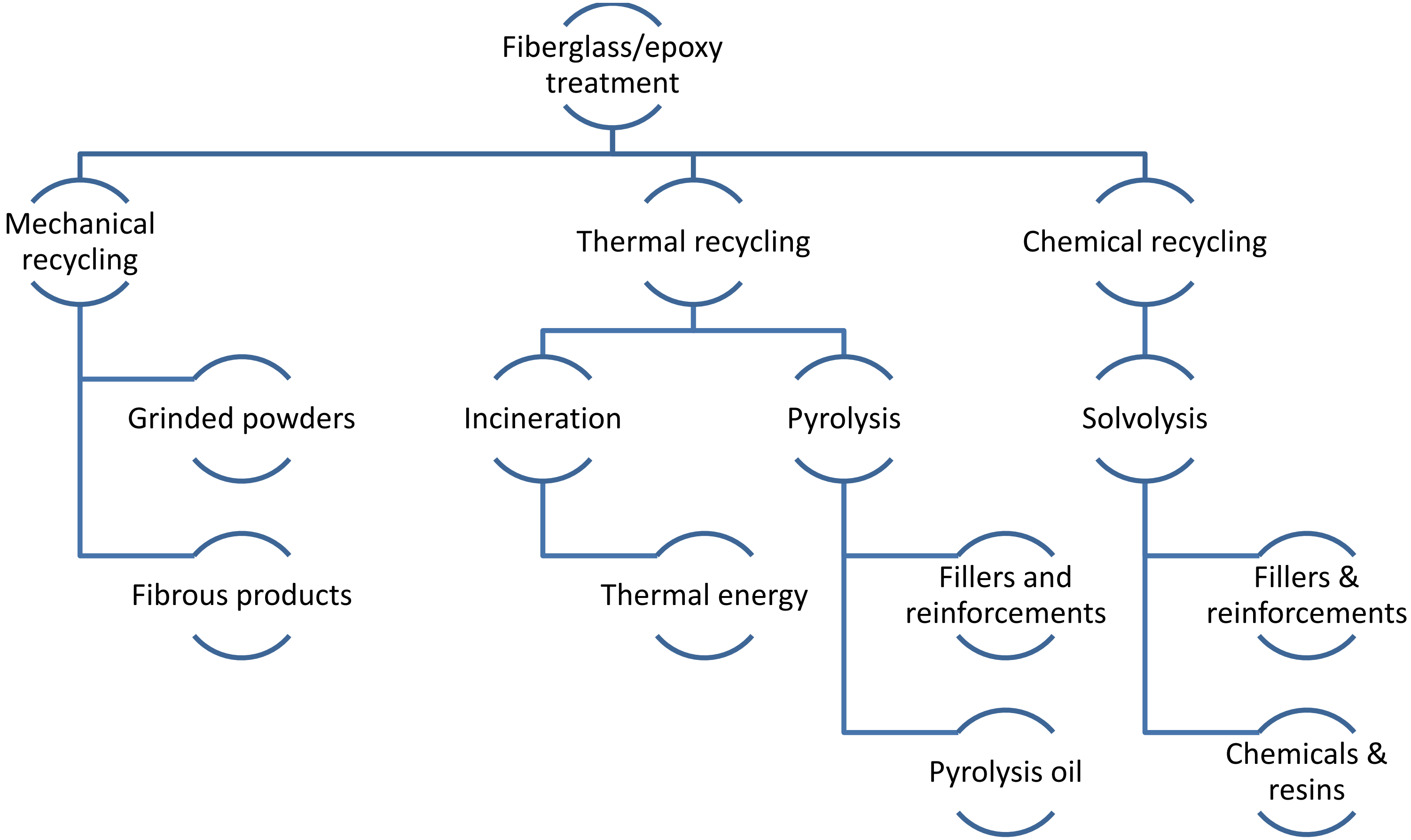


Figure 19 Pyrolysis process flow [10]

Figure 20 Recycling processes for wind turbine blades [18]



2.2.3 Wind turbine blades composite material as aggregate in concrete

The other option is using the composite material as aggregates replacing a fraction of limestone in concrete. Due to time constraint the main focus will be on the aggregate in concrete approach. There was a research done on the quality and performance of concrete with filler material from the blades at the University of Iowa in 2016. The findings of the research will be discussed in the following the section. Previous research on using composite material from the blades to replace limestones had shown promising results to be implemented for concrete roads and pavements. Although small fractions of composite aggregate replacing limestones within concrete showed that the strength can be increased, it still can't be applied for building application due to factors of corrosion and water adsorption which still needs more improvements [13].

There are different stages of preparing the epoxy fiber glass composite material, turning it into a composite aggregate applied in concrete. The processes are very challenging due to lack of adequate equipment available in producing the ideal resource/ composite aggregate.

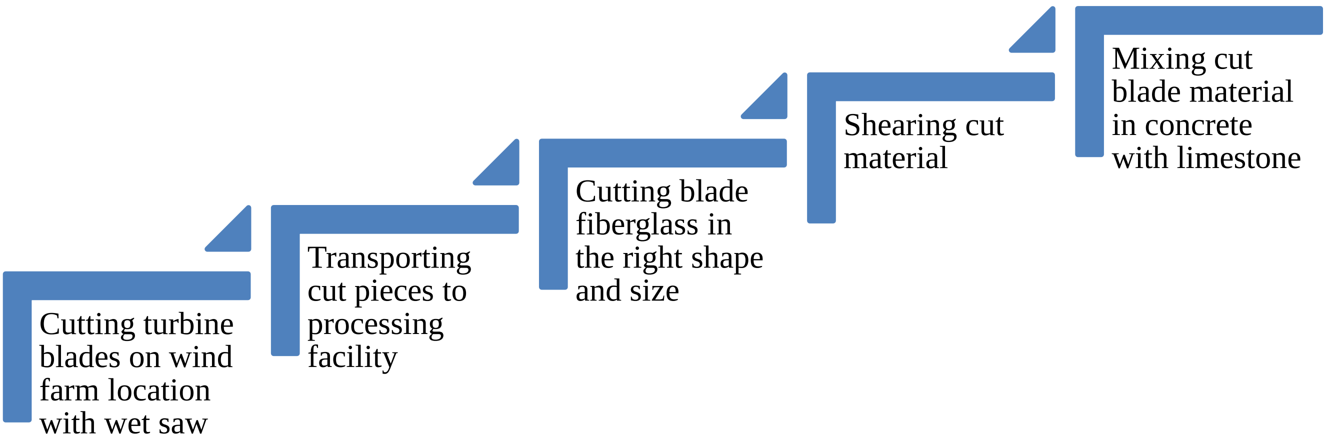


Figure 21 Process epoxy partially replacing limestone aggregates in concrete

The whole process of turning the turbine blade into aggregate to replace a portion of the limestone aggregate in concrete is given in the flowchart, Figure 21. First the blade will be cut on location after being dismantled from the rotor. After being cut in transportable pieces, the cut blades will be transported to the processing location where it will be further processed. At the process location the glass fiber material (epoxy) will be extracted from the blade. Epoxy material will then be cut in the ideal shape and sizes. The size should be between 1.3 and 2.5 cm and the shape of the edges should have different shapes. Edges of the cut epoxy material in the ideal shapes and size should be rough, a shearing process will be applied to achieve this. Rough edges are necessary for the aggregate to bond well with limestone and concrete paste. Last stage is then applying the fiber glass material in the mix of concrete and limestone. Through various experiments and tests in the past, a ratio below 25% Composite/ glass fiber aggregate and 75% limestone aggregate yielded the minimal compressive strength.

Three tests were conducted at the University of Iowa to inspect the performance of the produced concrete with the composite aggregate and these were:

- Compressive strength test
- Tensile strength test
- Shrinkage test
- Fog room test
- And corrosion test [13]

The results showed some positive results in the compressive and tensile strength measurements without the fog room and corrosion application. The Fog room treatment also yielded positive results

According to sources about 20% of the decommissioned W.T. blades can be refurbished and resold. During the decommissioning phase on location, the blades will carefully be dismantled and be transported as a whole. The transportation of the whole blades is the most complex part of the application as transporting large blades is capital and labor intensive. This is due to the trafficking permits, infrastructure and inadequate equipment in facilitating the whole dismantling and transportation process. After decommissioning, the blades are brought to a refurbishing facility where the blades will be further inspected. A repairing process will be followed after inspection. The repaired W.T. blades will then undergo another inspection and will then be certified. Finally the refurbished blades can be exported to EU and non-EU buyers. Although the refurbishing process is not really a sustainable option, it still prevents the EoL wind turbine blades ending up on landfills for the time being and prevention is one of the major objectives if the upside down pyramid for end of life applications is taken into consideration [19].

2.2.4 Refurbished and reusing the blades

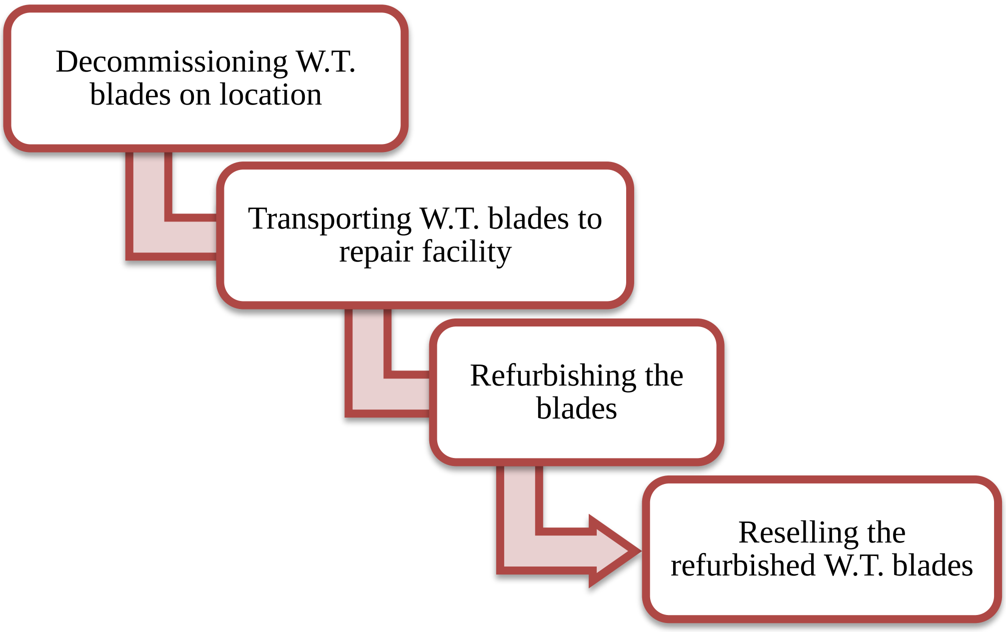


Figure 22 Refurbishing process of the W.T. blades

Aside from refurbishing, the blades or at least parts of the blades after cutting them in the required sizes and shapes, can be reused in building pedestrian bridges or housing shelters as shown in Figure 23 and Figure 24.

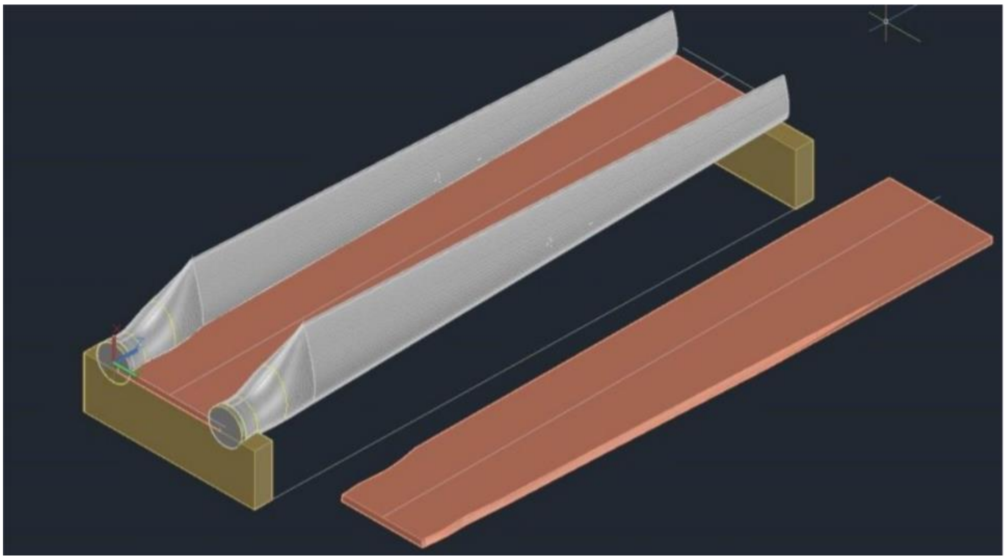


Figure 23 Reuse proposal: Pedestrian bridge [20]

Figure 24 Reuse example: emergency shelter [20]

2.2.5 Landfilling W.T. blades

Apart from Germany and other countries in which landfilling is completely prohibited, amortized W.T. blades are mostly landfilled. Landfilling is usually applied because of the lack of viable alternatives currently available and the fact that it is the easiest way to get rid of the non-usable blades. This process is a linear process and it is the least sustainable/ desirable method applied. If we look at Figure 25, the W.T. blades are decommissioned. The blades are then cut in transportable pieces and after that the cut blade pieces are transported to the landfill. Occasionally the blade pieces are first incinerated to reduce the size and are landfilled afterwards [12] & [13]

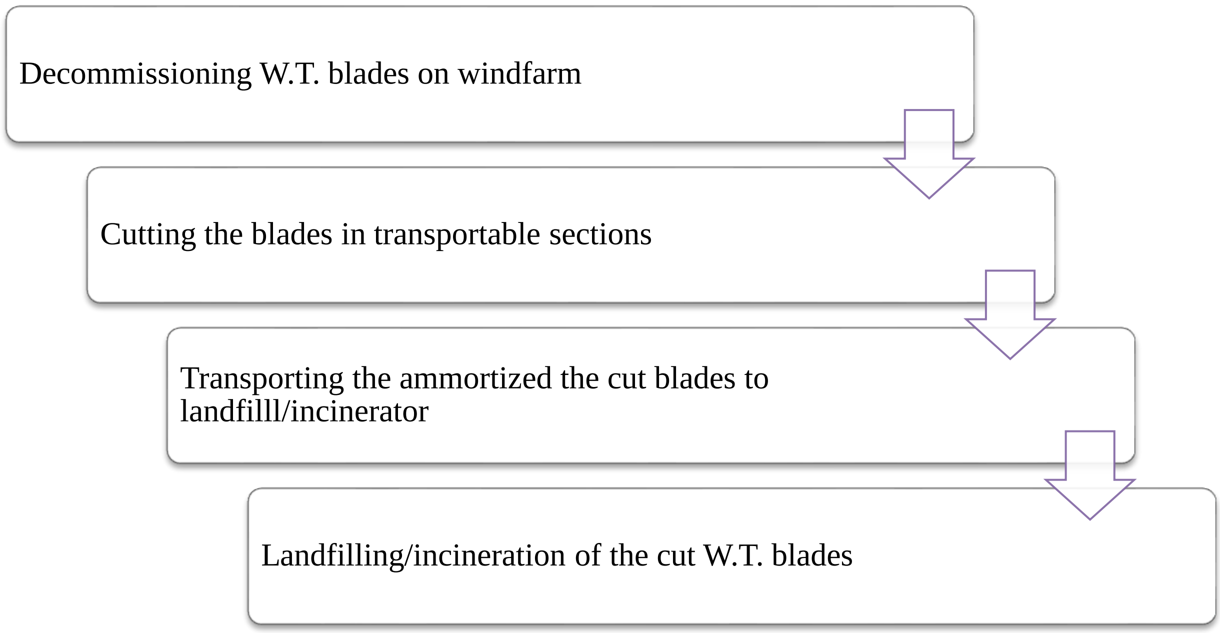


Figure 25 Landfilling the W.T. blades

2.3 Bottlenecks to implement current alternatives

Despite all the pros for each of the four applications, leaving out the most unsustainable approach, landfilling. There are a number of bottlenecks which need to be mended with. Bottlenecks or obstacles for implementing the at least three of the alternatives are:

- Permits required in transporting the decommissioned blades. Due to safety and traffic requirements, permits need to be applied to municipalities or government officials which have the authority to approve such permits
- Roads and waterways need to be cleared out when the wind turbine blades have to be transported to a facility where they will be further processed. This is definitely the case for the blades which will be refurbished or reused for bridges and other building applications. The blades usually remain intact or are cut in large remaining pieces which still need to be transported on large carriers (both on land and water)
- The W.T. blades are difficult to reverse engineer. Repairing damaged parts of the blade are very difficult replace and usually requires for that blade to be replaced, which can be cost intensive
- Little to no efficient dismantling equipment and vehicles for transporting the blades. The heavy equipment, shipping and truck industry should research and develop equipment, ships and trucks to transport the ever so growing blades in length. Since there is a rising trend in the length of the W.T. blades, transporting these lengthy blades have become complicated which makes this whole process not only risky, but also capital intensive

2.4 Tackling these bottlenecks possible/ impossible

Improvement of the three alternatives (pyrolysis, pavement and refurbishing) for processing or recycling the W.T. blades can be achieved through data collection from manufacturers, maintenance, dismantling and spatial planners. All the collected data can then be analyzed in utilizing methods and technology in realizing new and much efficient afterlife alternatives for the blades.

The bottlenecks can be tackled with the aid of the following:

- Designing the blades in such a manner which makes dismantling easier
- Coming up with adequate vehicles and equipment facilitating the dismantling and transportation process
- More research and studies should be done on finding ideal routes and ways how the current infrastructure can be improved, minimizing the costs and avoiding the permitting procedures
- Use of artificial intelligence can improve the monitoring and maintenance of the wind turbine blades. Artificial intelligence can be integrated in the design and maintenance inspection through flying drones with high definition cameras

2.5 Discussion

Despite the W.T. blades being difficult to recycle, there are fortunately a number of end of life applications which can be applied now or in the near future. There are mainly four applications which are considered for this dissertation and these are: pyrolysis, refurbishing, pavement and landfilling of the end of life blades. After a close look at the available options for recycling the wind turbine blades, the most viable solution for now are the pyrolysis and pavement applications while the other methods still need to be improved through research and development.

Due to the complexity of recycling the W.T. blades at the moment, most blades are concurrently landfilled and incinerated even when the Glass fiber material within the polymer matrix composite is non-combustible. There are limited methods available for afterlife applications of the blades, which are not widely applicable on a large scale yet due to the applications are still being developed or and are not feasible to be implemented currently.

While the recycling process is a complex issue, methods have been created and new ones are still being developed in tackling the issue. Some methods like pyrolysis and using W.T. blade aggregates in pavements have the potential to reduce the waste stream from decommissioned wind turbines. Replacing the thermoset material with thermoplastic may also be viable option, but this method is still being developed and tested. This is not the ideal solution for now as the blades are becoming bigger and larger in length, which has mainly to do with the ideal properties the current CRFP and GRFP composite materials possesses.

III Look at future more viable alternatives concerning the issue

For the Life Cycle Assessment (LCA) the software application GaBi will be used in simulating a scenario of “Cradle to Gate of recycling facility” of the wind turbine blades. The LCA will start with the dismantling and transportation phase and end with the recycling phase. For the purpose of analysis a comparison will be made between recycling and landfilling.

3.1 Are they technologically and economically feasible?

LCA will be conducted here. Based on the calculations and results an analysis will be made.

3.1.1 Life cycle assessment grave to gate

In this section a life cycle assessment (LCA) will be conducted for recycling the wind turbine blades. Due to time constraint and complexity of the whole process (from cradle to cradle), the scenario of grave to gate will be taken into consideration for this LCA. The assessment will be done with the LCA software GaBi education version.

3.1.1.1 Gate to Grave scenario

The gate to grave scenario involves the situation in which the wind turbine blades have reached the end of their lifecycle and need to be dismantled on location. After dismantling the blades, they will be transported back to a facility where it will either be stored or processed. The processes include incineration and recycling processes mentioned before in the report. The incineration and recycling processes will not be included in the LCA.

3.1.1.2 A blade’s life cycle

The life cycle of a blade can be divided into six stages:

1. Processing of raw materials
2. Manufacturing of the blades
3. Painting/coating application
4. Installation of a complete wind turbine system
5. Operation phase
6. Decommissioning and disposal of the blades [21]

3.1.1.3 Processing of raw materials

This process involves the production of fiberglass, farming and cutting balsawood at plantations, processing of metal ores for the necessary metals and packaging material [21].

3.1.2 Manufacturing of the blades

The manufacturing of the W.T. blades occurs at a blade manufacturing facility. Due to optimum exploitation of resources waste materials from manufacturing processes are broken down into small fractions [21].

3.1.2.1 Painting/coating application

The epoxy and fiber glass resin blades are painted with the aid of coating applications [21]. Coating is usually applied with polyutherane based high pressured spray.

3.1.3 Installation of a complete wind turbine system

Wind turbines are installed with the using of cranes, lifting the towers, nacelle, hub and blades to the designated heights. Diesel consumption for lifting the blades at time of wind turbine installation is 140 liters per set of blades [21].

3.1.3.1 Operation phase

A wind turbine system has a designed and tested lifetime of around 20 years. During this lifetime, a 2.3 MW wind turbine for example will produce approximately 159.7 GWh. It should be mentioned that no maintenance or replacement is involved for the LCA [21].

3.1.4 Decommissioning and disposal of the blades

The blades are dismantled in this phase. After dismantling the blades, most of the blades end up on landfills, 20% of the blades can be refurbished and reused and a small amount of the blades are recycled [21].

Material content of a W.T. blade [21]

Fiberglass	54.86%
Epoxy	32.90%
Wood	7.98%
Paint & Filler	1.40%
Stainless steel	1.24%
Polypropylene	0.84%
Nylon	0.51%
Bronze	0.20%
Polyester	0.03%
Aluminum	0.02%
Rubber	0.02%
Polyethylene	0.01%

Table 4 Material content in the W.T. blades

In the decommissioning phase the following inputs have been included based on practical information obtained from a refurbished wind turbine blade selling entity. The costs for equipment, labor and transportation is a rough assumption based on the data which was provided.

Four grave scenarios were chosen for the LCA, as these were the most applicable solutions available at the moment. The inputs and outputs were also obtained from stakeholders, varying from governmental to private and non-profitable organizations. All of the data used for the LCA were rough estimates available, taking careful consideration of time and accessibility into account as limitations for an ideal scientific research approach. Nevertheless, the LCA was conducted as realistic as possible by comparing similar recycling processes existing in the educational version of the software.

The reasons for the chosen options are:

- Available data
- Maturity of the process and its application at the moment
- Feasibility

The chosen grave scenarios are:

- Pyrolysis of wind turbine blades
- Refurbishing and reselling wind turbine blades
- Transporting the blades to landfills or incinerator
- Using the EoL blades for making pavements

Water jet cutting average use of water is 1.9-3.8 Liters/ minute. Assume 3.8 liters/minute and the time to cut one blade is approximately 2 hours, which results in 3.8x120 min = 456 liters/blade. There are 3 blades, which adds to 456x3= 1368 L in total.

Weight of one blade from a 2MW wind turbine model is estimated to be 6500 kg or 6.5 tons. A wind turbine mostly has 3 blades, which totals to around 19.5 tons [22]. When the blades are cut and after that shredded there is a loss of around 25% of material (reference). This is usual for mechanical recycling.

3.1.5 LCA of the four applications

The following simulation has been conducted for only one wind turbine. No timeframe is incorporated for this L.C.A. The LCA is conducted per dismantling of one wind turbine at a windfarm with an average distance of 300 km away from the various processing facilities.

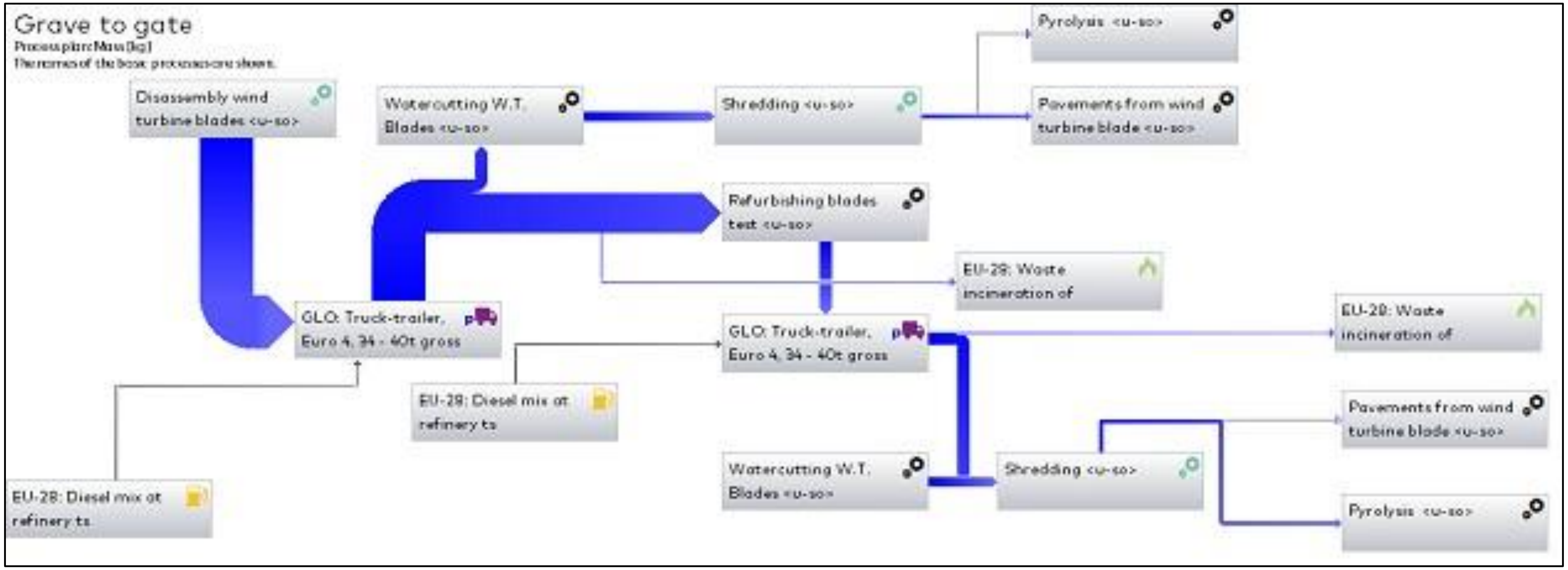


Figure 26 LCA Recycling W.T. Blades processes

The LCA of each process is merely an indication on what the effects the processes might have on the environment. Not all inputs and outputs of each flow and processes were available due to the restriction of the education version of GaBi. Figure 26 shows the overall view of the chosen EoL processes. The wind turbine blades will first be dismantled. After the dismantling/disassembly phase a portion of blades will be incinerated or landfilled. Another portion will be refurbished and the two other portions will first be cut by a waterjet cutter. After the blades are cut by a waterjet cutter one portion of the cut blades will undergo the pyrolysis process and the other portion will first be shredded and the will be utilized for the pavement application. For the pavement application the shredded materials occasionally also undergoes a shearing process before utilized for the pavements. The flow process also includes a scenario after the wind turbine blades are refurbished and have reached their end of life. The blades have three End of life options then and these are either incineration or pyrolysis or pavement application. Landfilling has been left out in this case, but can be substituted for the incineration process. Incineration was chosen in this case because the aim is to reduce the amount of wind turbine blades ending up as waste at landfills.

Number	Climate and land use change midpoints [Recipe 2016 (H)]
1	*Climate change, default, excl biogenic carbon [kg CO2 eq.]*
2	*Climate change, incl biogenic carbon [kg CO2 eq.]*
3	*Fine Particulate Matter Formation [kg PM2.5 eq.]*
4	*Fossil depletion [kg oil eq.]*
5	*Freshwater Consumption [m3]*
6	*Freshwater ecotoxicity [kg 1,4 DB eq.]*
7	*Freshwater Eutrophication [kg P eq.]*
8	*Human toxicity, cancer [kg 1,4-DB eq.]*
9	*Human toxicity, non-cancer [kg 1,4-DB eq.]*
10	*Ionizing Radiation [Bq C-60 eq. to air]*
11	*Land use [Annual crop eq.·y]*
12	*Marine ecotoxicity [kg 1,4-DB eq.]*
13	*Marine Eutrophication [kg N eq.]*
14	*Metal depletion [kg Cu eq.]*
15	*Photochemical Ozone Formation, Ecosystems [kg NOx eq.]*
16	*Photochemical Ozone Formation, Human Health [kg NOx eq.]*
17	*Stratospheric Ozone Depletion [kg CFC-11 eq.]*
18	*Terrestrial Acidification [kg SO2 eq.]*
19	*Terrestrial ecotoxicity [kg 1,4-DB eq.]*

Table 5 Midpoint criteria for environmental impact

The 19 midpoints or criteria's for an environmental impact assessment is given in Table 5. Each criteria has its own unit and from point 1 and 2 we see that the climate change due to carbon emissions is the main cause of concern when it comes to the environmental impact assessment

The life cycle assessment conducted with the GaBi LCA education software based on assumptions derived from available literature. The three blades are from the model vestas V82 of round 2 MW model and therefore the results are only applicable for this model as the design and materials used in blades are diverse. Total weight of the 3 W.T. blades amounts to 19.5 t, with average of 6.5t per blade [10]. For a more detailed and accurate LCA for recycling the wind turbine blades, more data is required.

3.1.5.1 Wind turbine blades in the Pavement application

The lifecycle assessments of the aforementioned processes are given below. First process shown below in Figure 27 is the pavement application. The process begins with the dismantling of the components of which the W.T. blades is the chosen component of a wind turbine. After the dismantling of the blades, the blades are cut with a waterjet cutter and after being cut the pieces of the blades are shredded into small size granules between 2.5 and 5 cm. Cutting of the blades is usually done on location and shredding can be done at the disassembly location or at a facility. In this scenario the blades are shredded at the disassembly location. Sometimes the granules also need to be sheared in order to get rough edges. The shearing process is not included as it did not have much effect on the roughness of the granules referenced from the literature [13]. After the shredding process the granules are transported by a cargo truck to the facility where the granules are used in manufacturing the pavements.

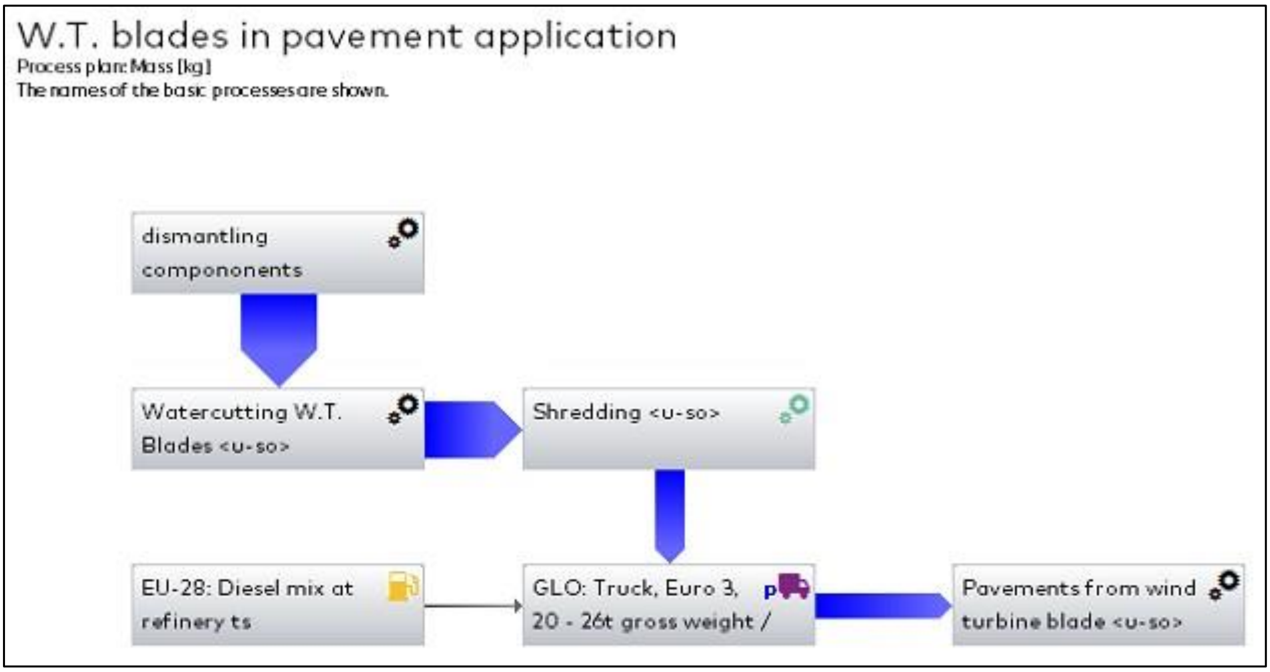


Figure 27 Process flow of the pavement application

Results of the lifecycle assessment are given below:

W.T. blades in pavement application <LC> [applied unit]	Quantity
Climate change, default, excl biogenic carbon [kg CO2 eq.]	2,02E+05
Climate change, incl biogenic carbon [kg CO2 eq.]	2,02E+05
Fine Particulate Matter Formation [kg PM2.5 eq.]	0,11
Fossil depletion [kg oil eq.]	23,3
Freshwater Consumption [m3]	0,101
Freshwater ecotoxicity [kg 1,4 DB eq.]	0,0134
Freshwater Eutrophication [kg P eq.]	0,000372
Human toxicity, cancer [kg 1,4-DB eq.]	0,019
Human toxicity, non-cancer [kg 1,4-DB eq.]	6,97
Ionizing Radiation [Bq C-60 eq. to air]	0,0306
Land use [Annual crop eq.·y]	5,81
Marine ecotoxicity [kg 1,4-DB eq.]	0,0405
Marine Eutrophication [kg N eq.]	0,00199
Metal depletion [kg Cu eq.]	0,0439
Photochemical Ozone Formation, Ecosystems [kg NOx eq.]	5,18
Photochemical Ozone Formation, Human Health [kg NOx eq.]	3,52
Stratospheric Ozone Depletion [kg CFC-11 eq.]	1,82E-05
Terrestrial Acidification [kg SO2 eq.]	0,323
Terrestrial ecotoxicity [kg 1,4-DB eq.]	2,97

Table 6 Results for the W.T. blades in pavement application L.C.A.

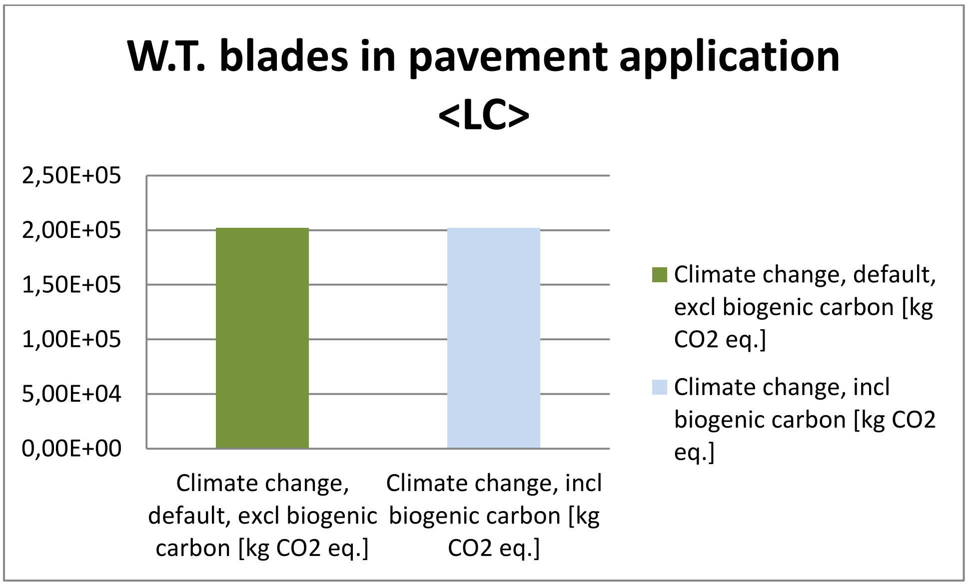


Figure 28 Graph of climate change for W.T.blades in pavement application

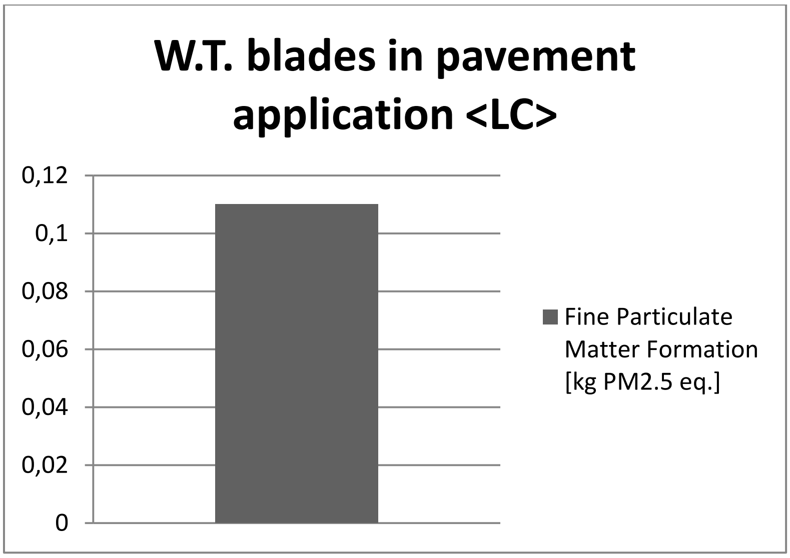


Figure 29 Graph of fine particulate matter formation for W.T. blades in pavement application

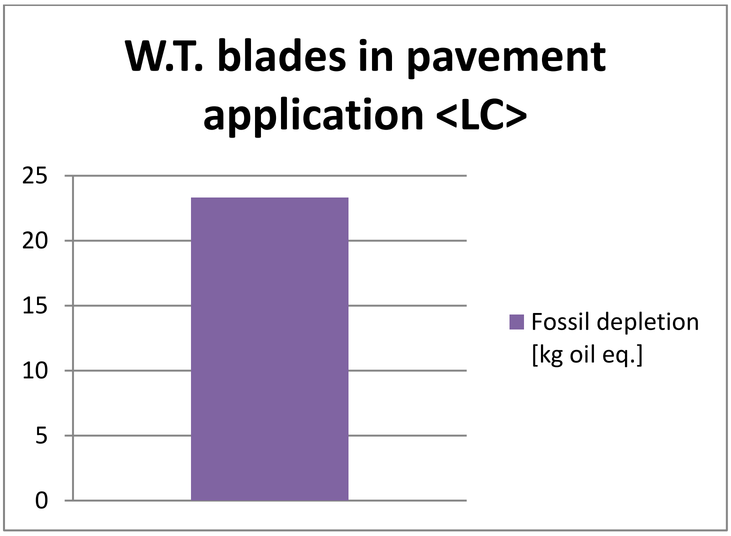


Figure 30 Graph of fossil depletion for W.T blades in pavement application

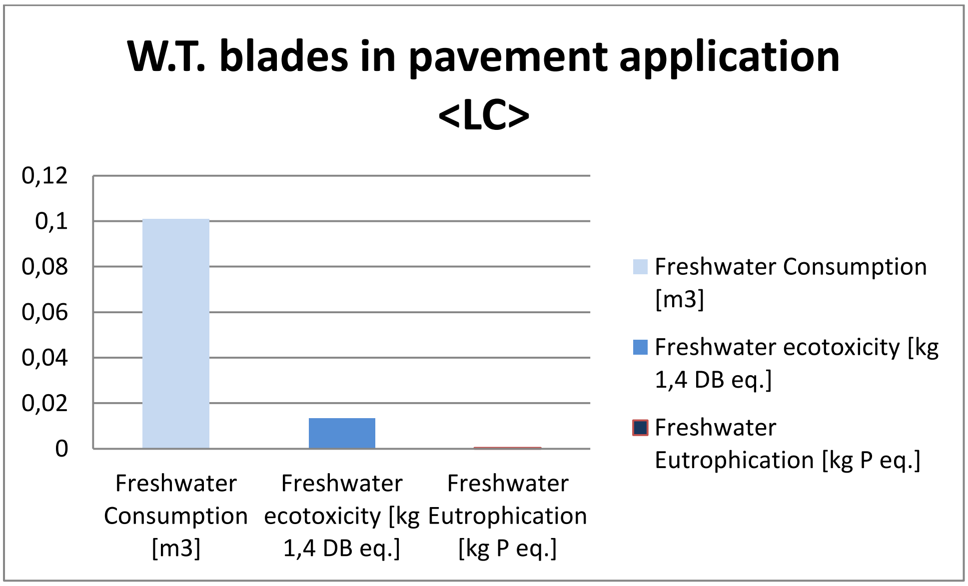


Figure 31 Graph pf freshwaterconsumption, -ecotoxicity and -eutrophication for W.T. blades in pavement application

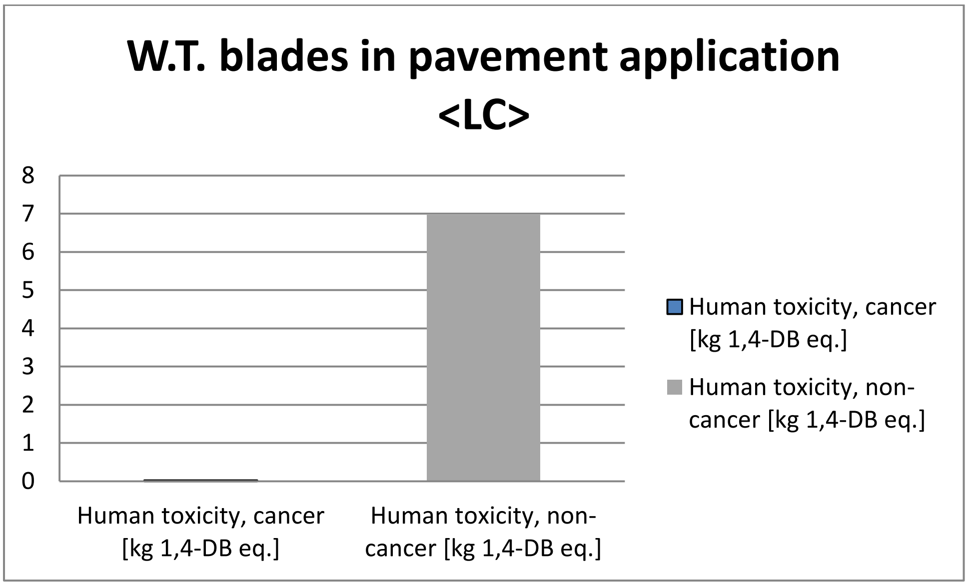


Figure 32 Graph of human toxicity (carcinogenic & non-carcinogenic) for W.T. blades in pavement application

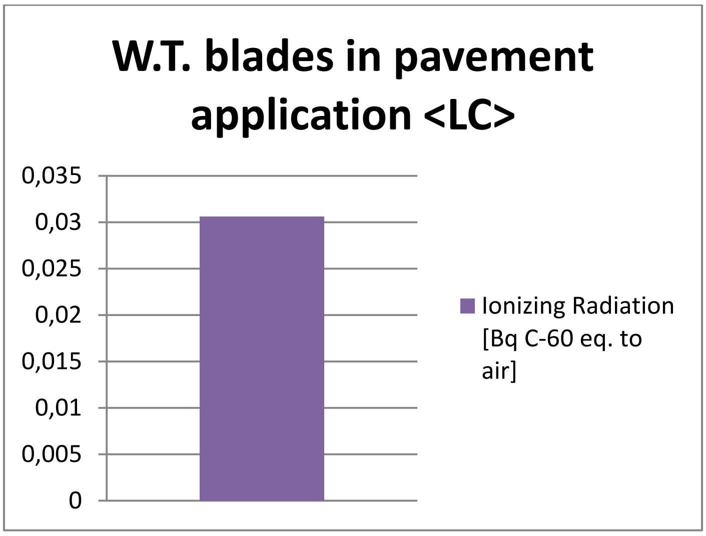


Figure 33 Graph of ionizing radiation for W.T. blades in pavement application

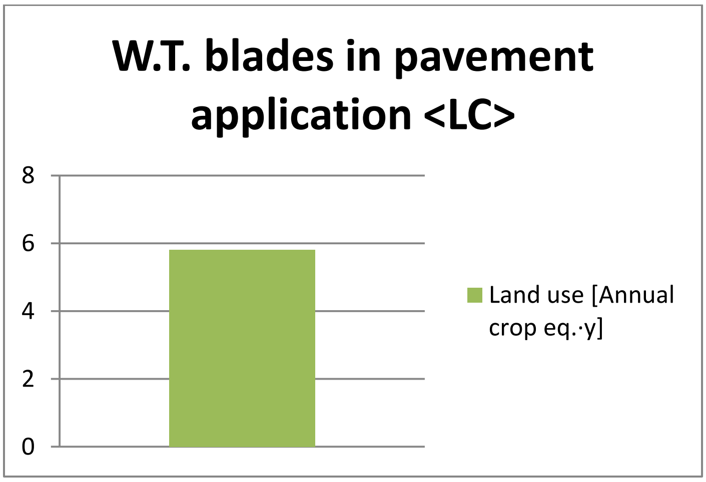


Figure 34 Graph of land use for W.T. blades in pavement application

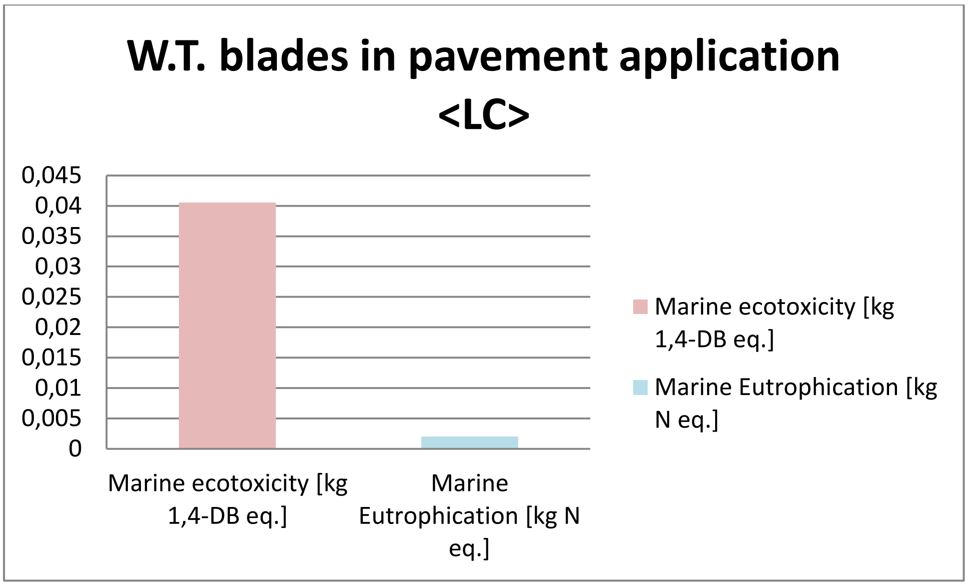


Figure 35 Graph of Marine-ecotoxicity and - eutrophication for W.T. blades in pavement application

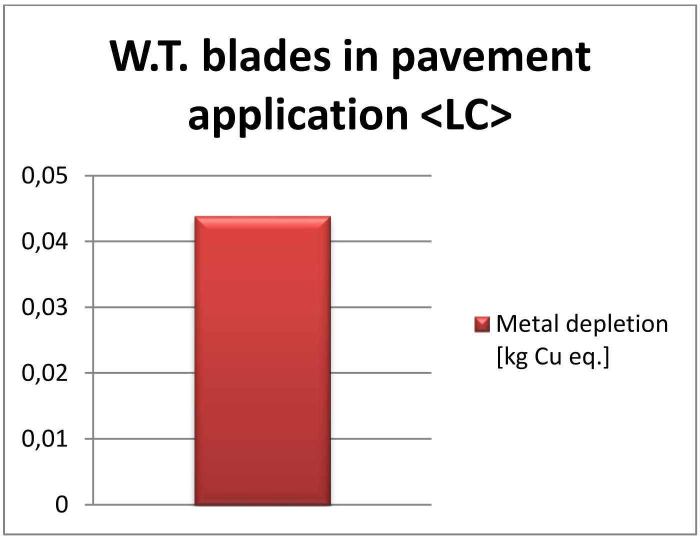


Figure 36 Graph of metal depletion for W.T. blades in pavement application

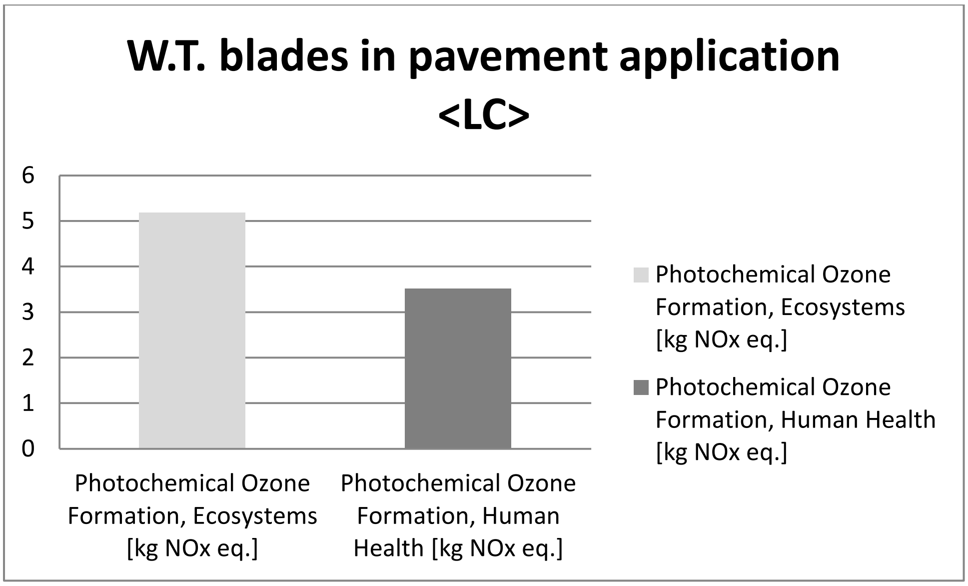


Figure 37 Graph of photochemical ozone formation ecosystems & photochemical ozone formation human for W.T. blades in pavement application

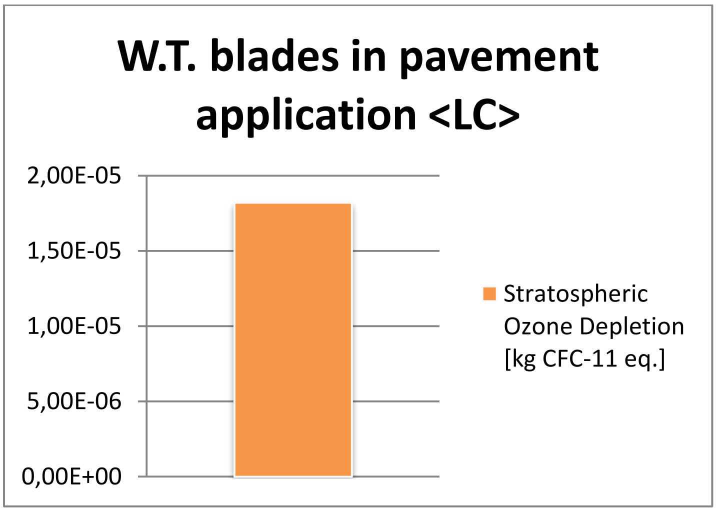


Figure 38 Graph of stratospheric ozone depletion for W.T. blades in pavement application

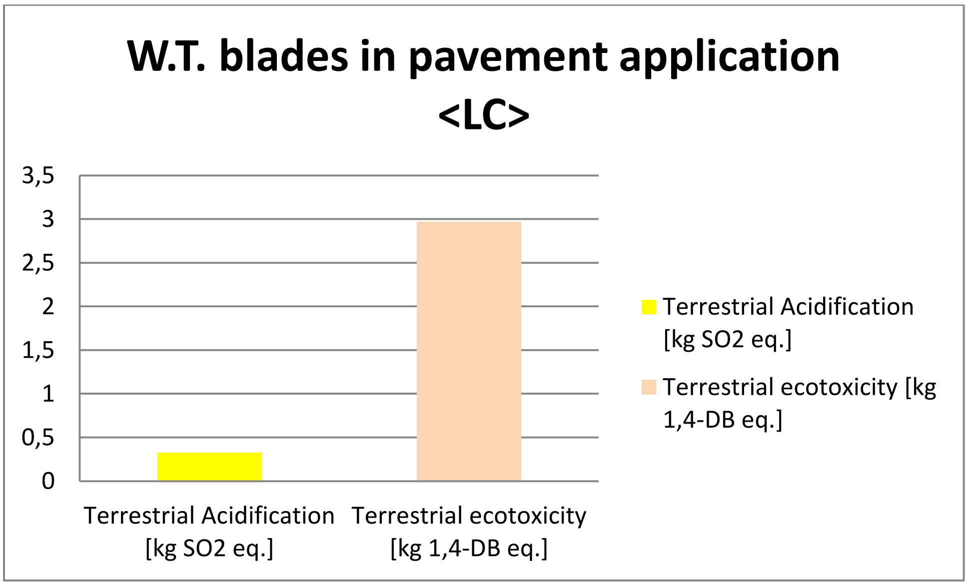


Figure 39 Graph of terrestial- acidification & -ecotoxicity for W.T. blades in pavement application

3.1.5.2 Pyrolysis of the W.T. blades

In the pyrolysis process, the blades are dismantled. After dismantling the blades are in cut in pieces in order to transport the blades to facility where the pyrolysis process will take place. As previously stated the pyrolysis process produces steam and pyrolysis oil which can be used to generate electrical energy which can be distributed to households and private sector. All of this is illustrated in Figure 40.

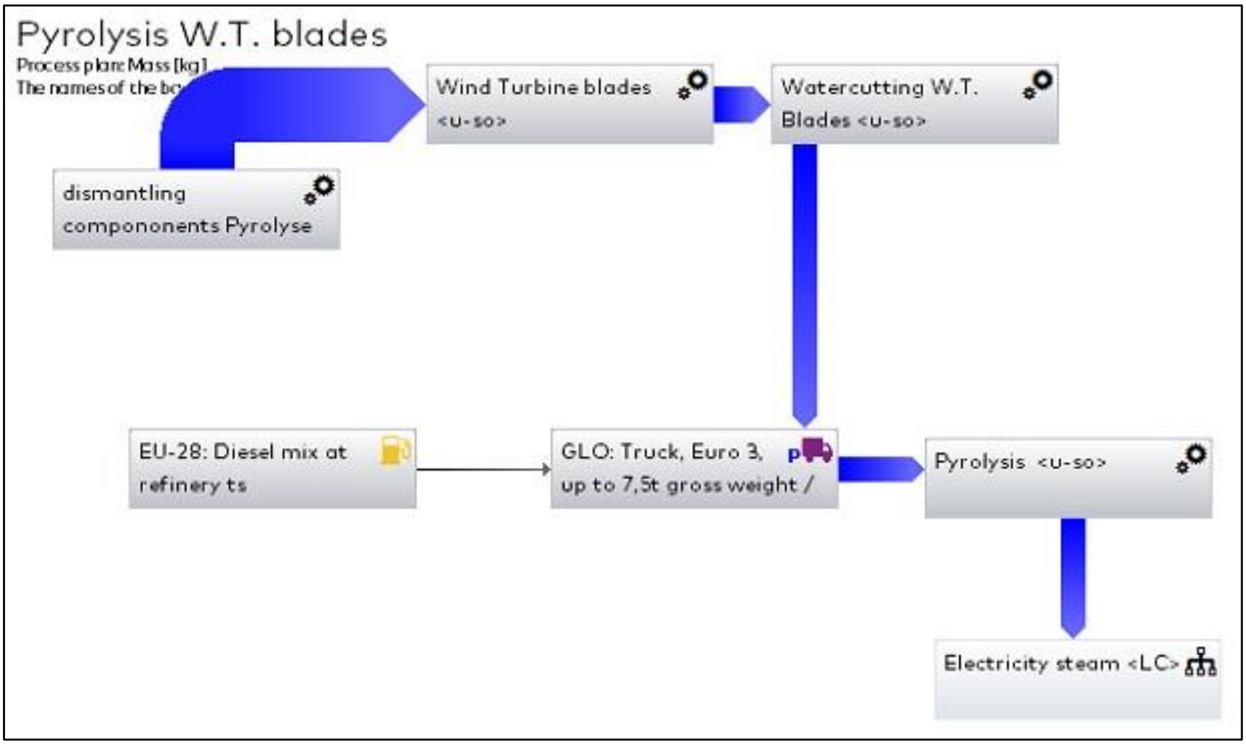


Figure 40 Flow for the pyrolysis of the wind turbine blade process

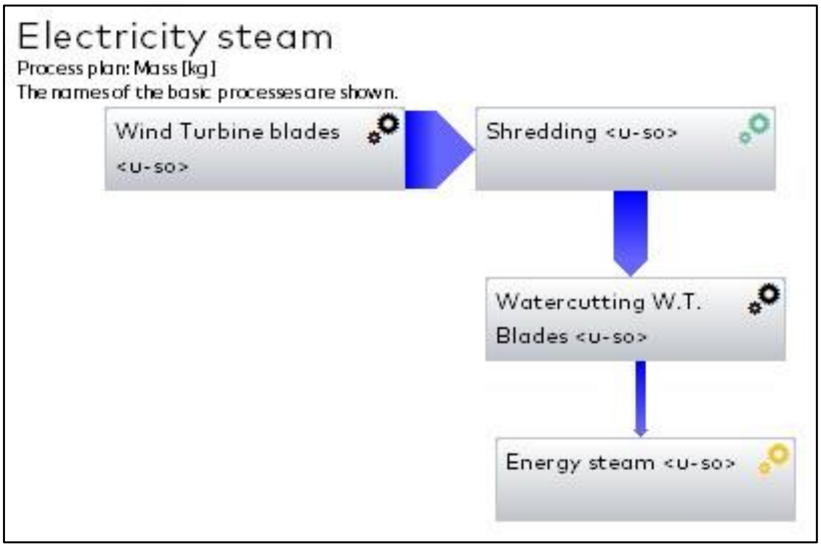


Figure 41 Flow of electricity steam

The given flow in Figure 41 Flow of electricity steam is part of the flow shown in Figure 40 Flow for the pyrolysis of the wind turbine blade process.

Results for the LCA of the pyrolysis application are given below:

Pyrolysis W.T. blades <LC> [applied unit]	Quantity
Climate change, default, excl biogenic carbon [kg CO2 eq.]	1,69E+04
Climate change, incl biogenic carbon [kg CO2 eq.]	1,69E+04
Fine Particulate Matter Formation [kg PM2.5 eq.]	0,696
Fossil depletion [kg oil eq.]	168
Freshwater Consumption [m3]	0,731
Freshwater ecotoxicity [kg 1,4 DB eq.]	0,0965
Freshwater Eutrophication [kg P eq.]	0,00269
Human toxicity, cancer [kg 1,4-DB eq.]	0,137
Human toxicity, non-cancer [kg 1,4-DB eq.]	50,4
Ionizing Radiation [Bq C-60 eq. to air]	0,221
Land use [Annual crop eq.·y]	42
Marine ecotoxicity [kg 1,4-DB eq.]	0,293
Marine Eutrophication [kg N eq.]	0,0144
Metal depletion [kg Cu eq.]	0,317
Photochemical Ozone Formation, Ecosystems [kg NOx eq.]	36,7
Photochemical Ozone Formation, Human Health [kg NOx eq.]	24,8
Stratospheric Ozone Depletion [kg CFC-11 eq.]	0,000134
Terrestrial Acidification [kg SO2 eq.]	2,09
Terrestrial ecotoxicity [kg 1,4-DB eq.]	21,5

Table 7 Results for the LCA of the Pyrolysis of the blades process

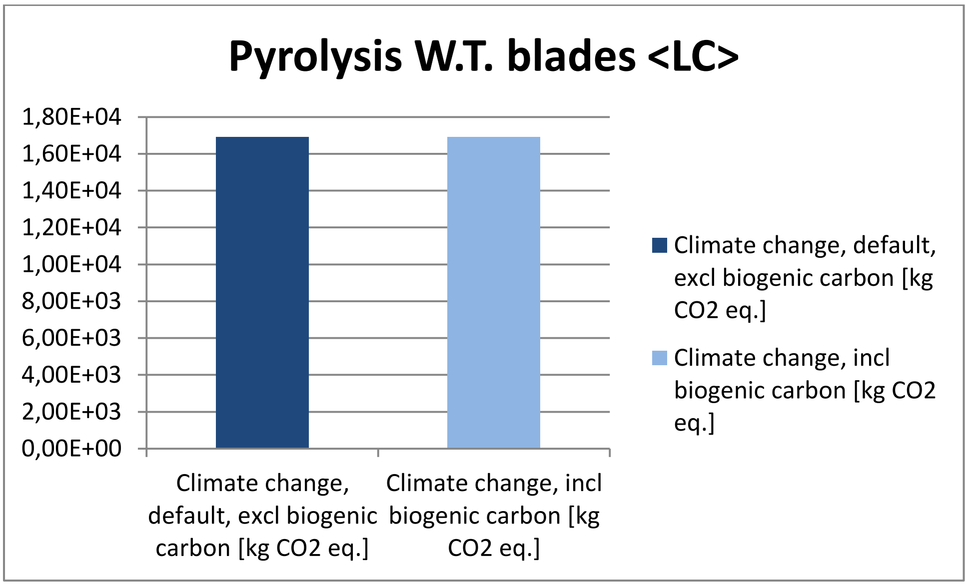


Figure 42 Graph of climate change for Pyrolysis of the W.T. blades process

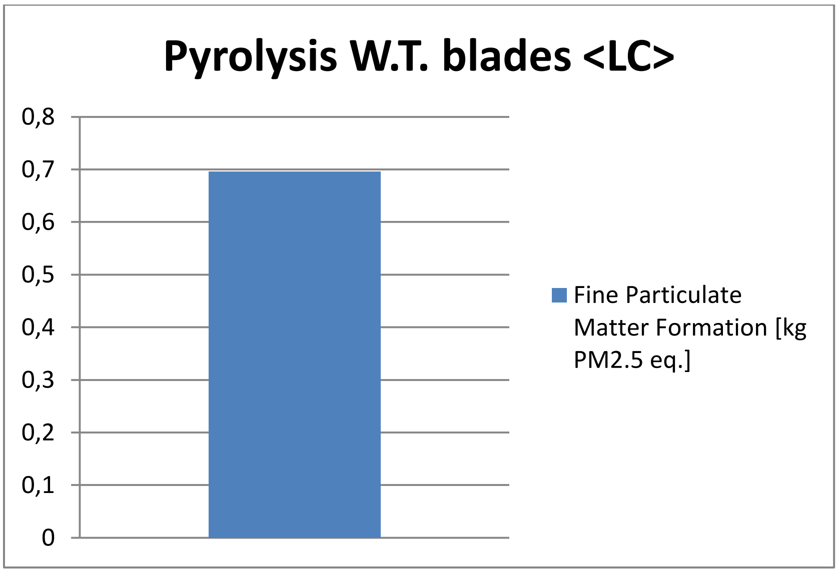


Figure 43 Graph of fine particulate matter formation for Pyrolysis of the W.T. blades process

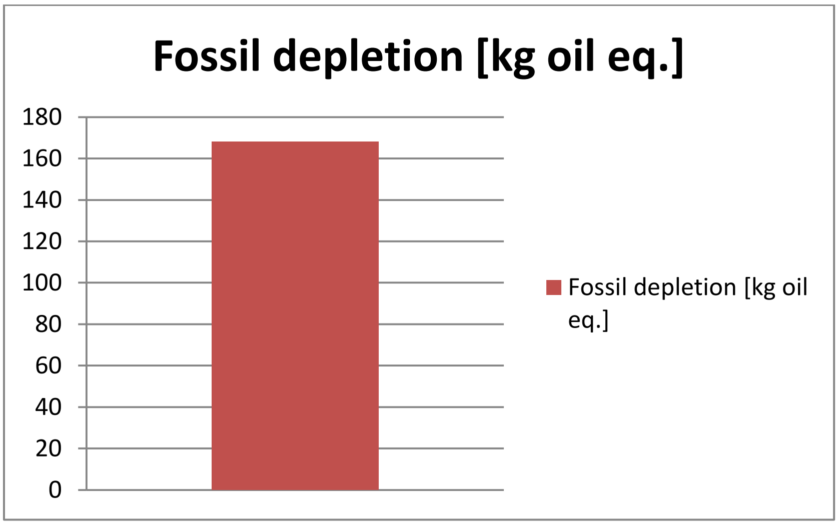


Figure 44 Graph of fossil depletion for Pyrolysis of the W.T blades process

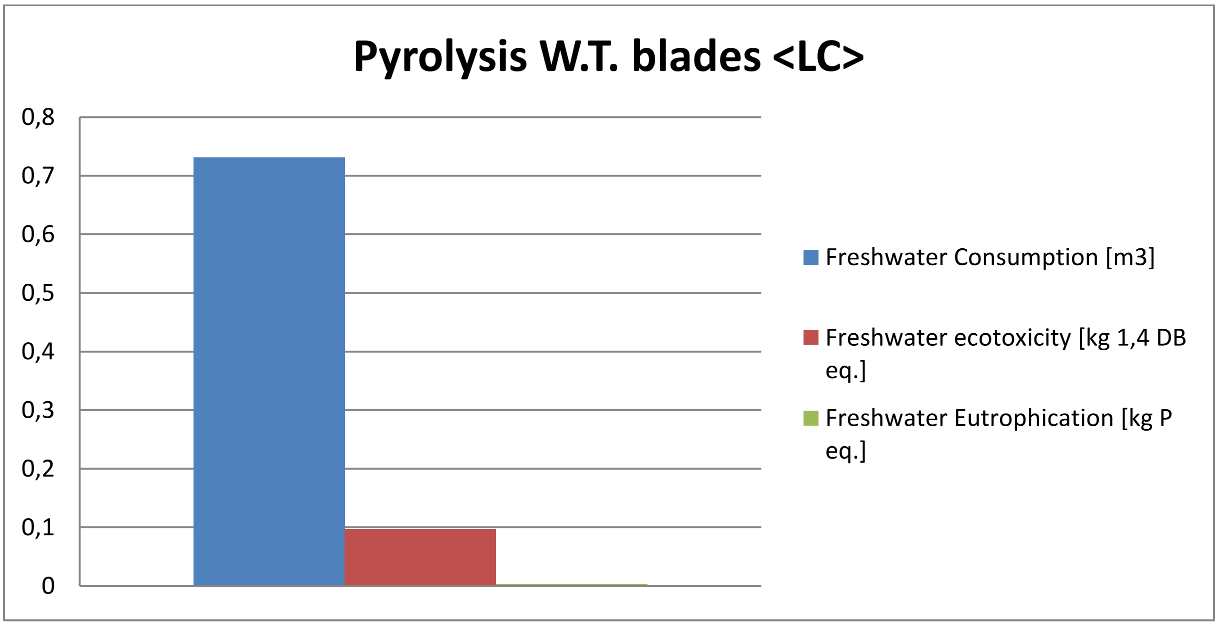


Figure 45 Graph of freshwater-consumption, -ecotoxicity and -eutrophication for Pyrolysis of the W.T. blades process

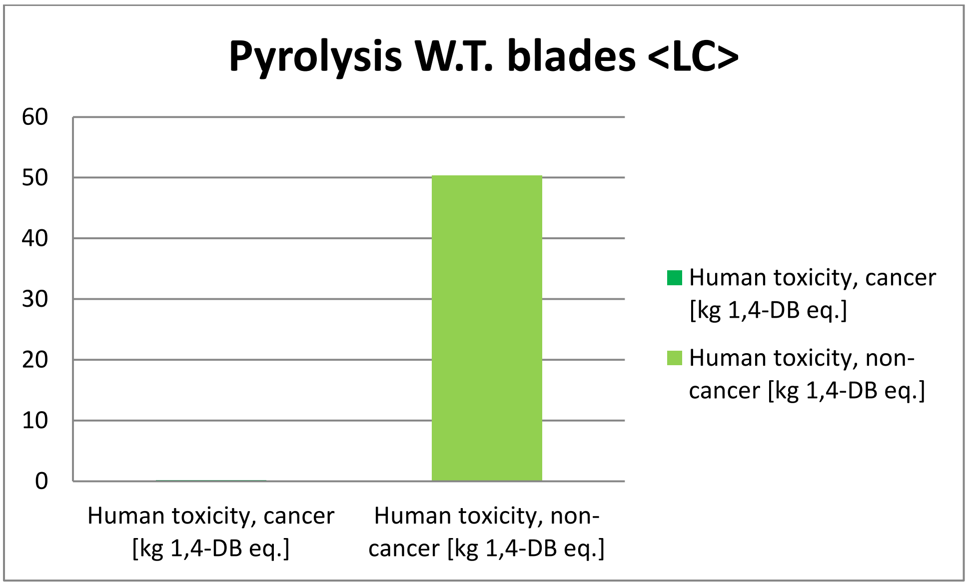


Figure 46 Graph of human toxicity (carcinogenic & non-carcinogenic) for Pyrolysis of the W.T. blades process

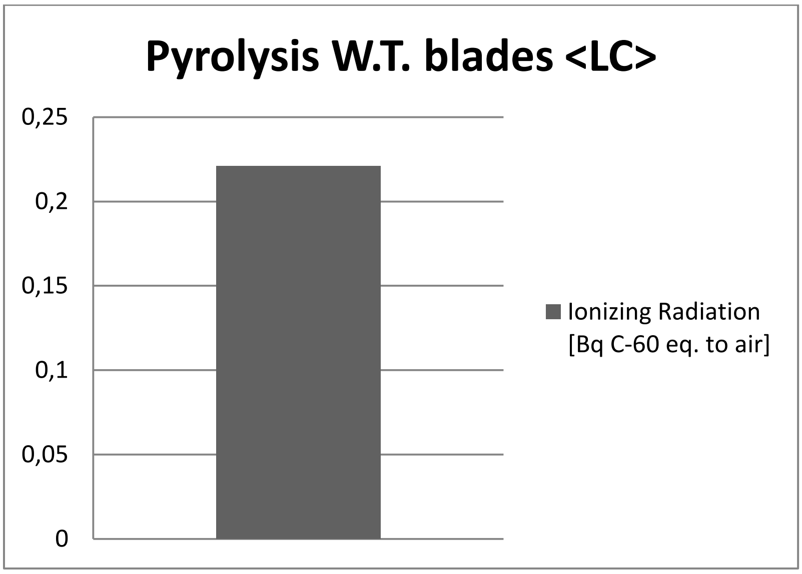


Figure 47 Graph of ionizing radiation for Pyrolysis of the W.T. blades process

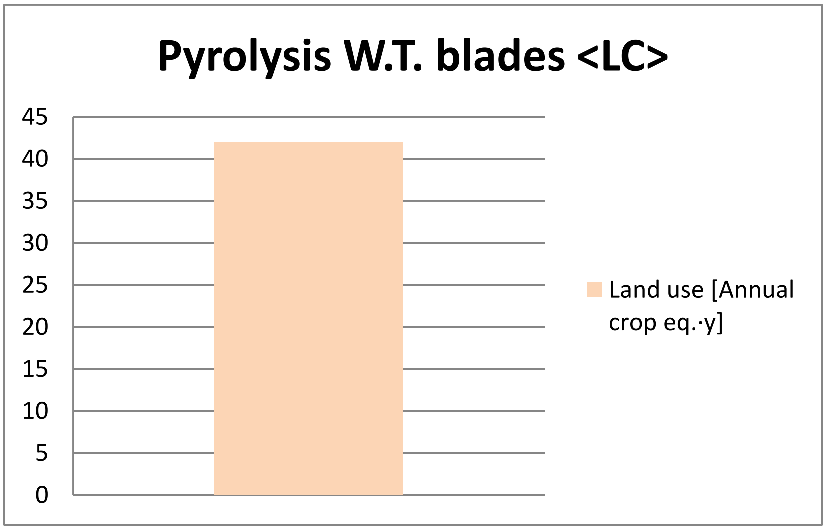


Figure 48 Graph of land use for Pyrolysis of the W.T. blades process

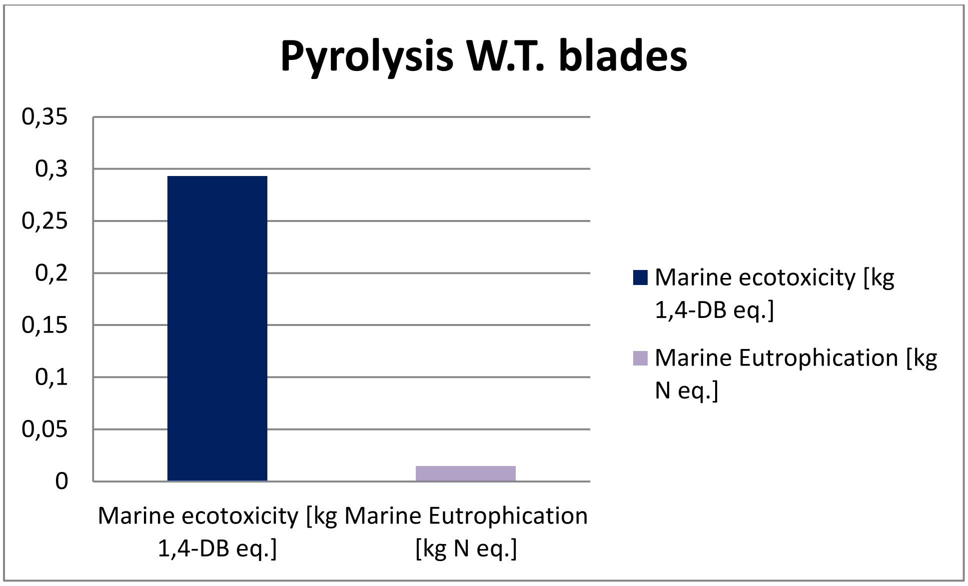


Figure 49 Graph of Marine-ecotoxicity and - eutrophication for Pyrolysis of the W.T. blades process

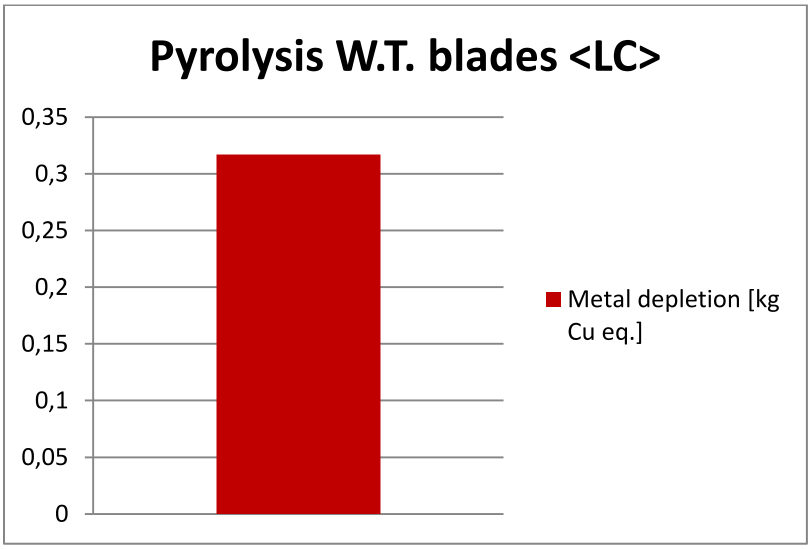


Figure 50 Graph of metal depletion for Pyrolysis of the W.T. blades process

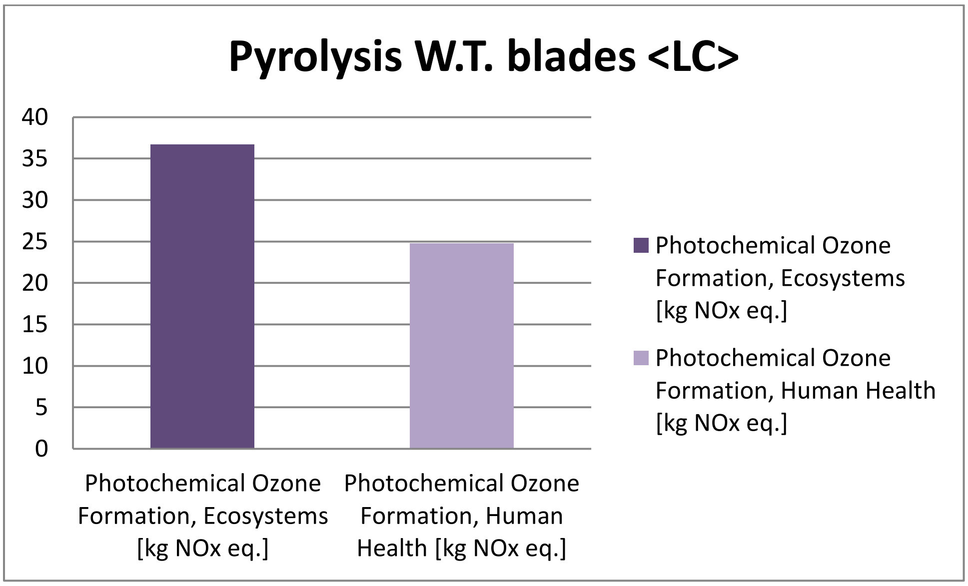


Figure 51 Graph of photochemical ozone formation ecosystems & photochemical ozone formation human for Pyrolysis of the W.T. blades process

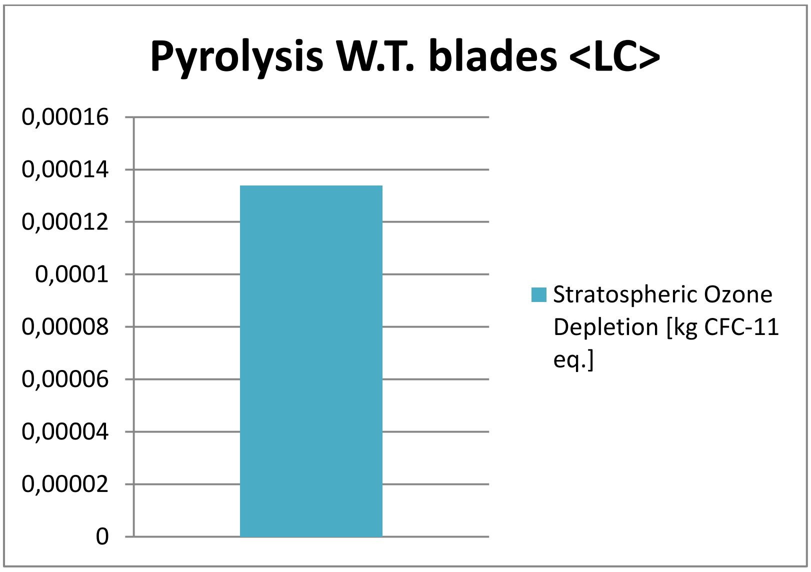


Figure 52 Graph of stratospheric ozone depletion for Pyrolysis of the W.T. blades process

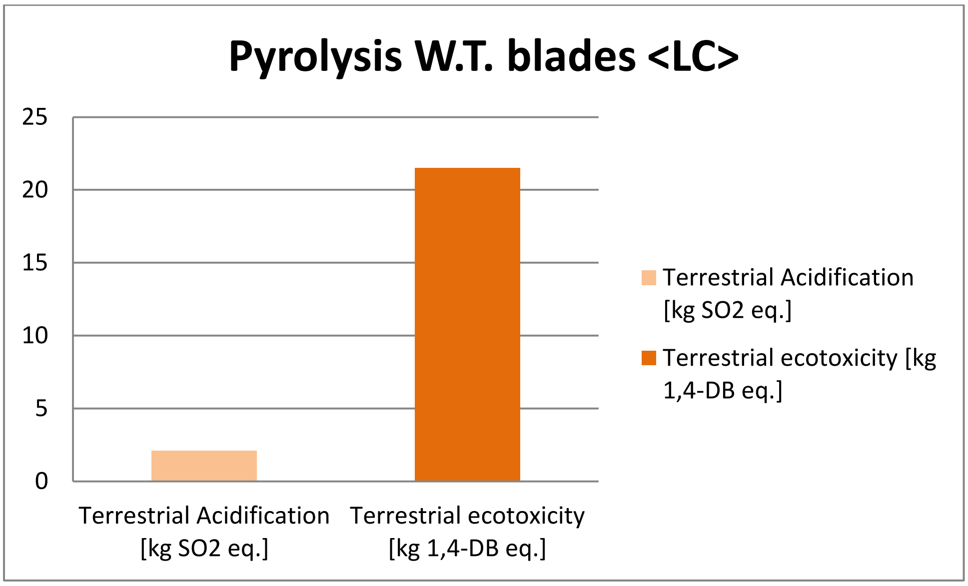


Figure 53 Graph of terrestial- acidification & -ecotoxicity for Pyrolysis of the W.T. blades process

3.1.5.3 Refurbishing of the W.T. blades

The refurbishment of the wind turbine blades is a simple process when we look at the process flow diagram indicated in Figure 54. After dismantling the blades at the designated windfarm, the blades are inspected. Inspection is necessary to see if the blades can be repaired. After close inspection the blades are transported to the refurbishing facility where the blades will be repaired and coated. The refurbished W.T. blades will then be inspected again and after that will get a certification which permits the blades to be sold to local and foreign buyers.

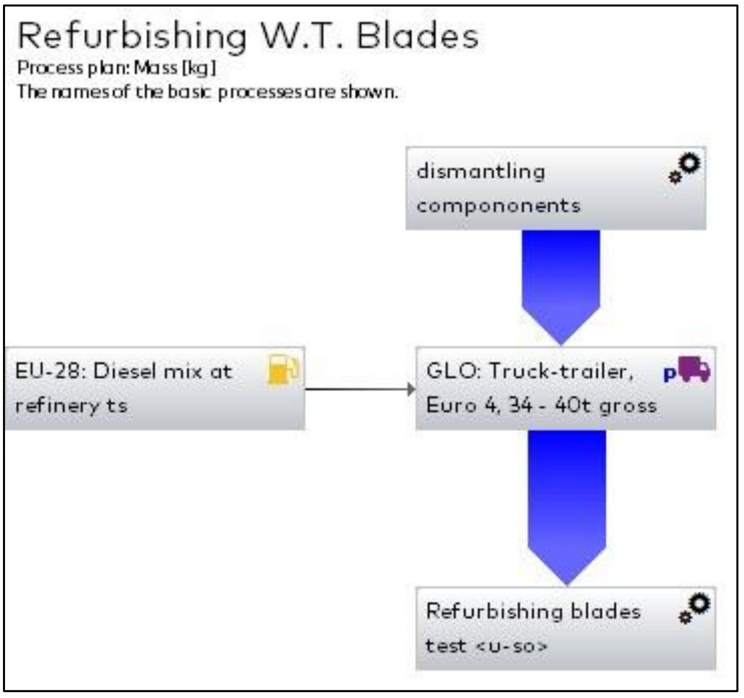


Figure 54 Process-flow refurbishing the W.T. blades

Results for the LCA of the refurbishing of the W.T. blades are given below:

Refurbishing W.T. Blades <LC> [applied unit]	Quantity
Climate change, default, excl biogenic carbon [kg CO2 eq.]	3,12E+03
Climate change, incl biogenic carbon [kg CO2 eq.]	3,12E+03
Fine Particulate Matter Formation [kg PM2.5 eq.]	0,113
Fossil depletion [kg oil eq.]	37,3
Freshwater Consumption [m3]	0,162
Freshwater ecotoxicity [kg 1,4 DB eq.]	0,0214
Freshwater Eutrophication [kg P eq.]	0,000595
Human toxicity, cancer [kg 1,4-DB eq.]	0,0299
Human toxicity, non-cancer [kg 1,4-DB eq.]	11,2
Ionizing Radiation [Bq C-60 eq. to air]	0,0489
Land use [Annual crop eq.·y]	9,3
Marine ecotoxicity [kg 1,4-DB eq.]	0,0648
Marine Eutrophication [kg N eq.]	65
Metal depletion [kg Cu eq.]	0,0703
Photochemical Ozone Formation, Ecosystems [kg NOx eq.]	7,84
Photochemical Ozone Formation, Human Health [kg NOx eq.]	5,19
Stratospheric Ozone Depletion [kg CFC-11 eq.]	4,84E-05
Terrestrial Acidification [kg SO2 eq.]	0,359
Terrestrial ecotoxicity [kg 1,4-DB eq.]	4,76

Table 8 Results for refurbishing of the W.T. blades application L.C.A.

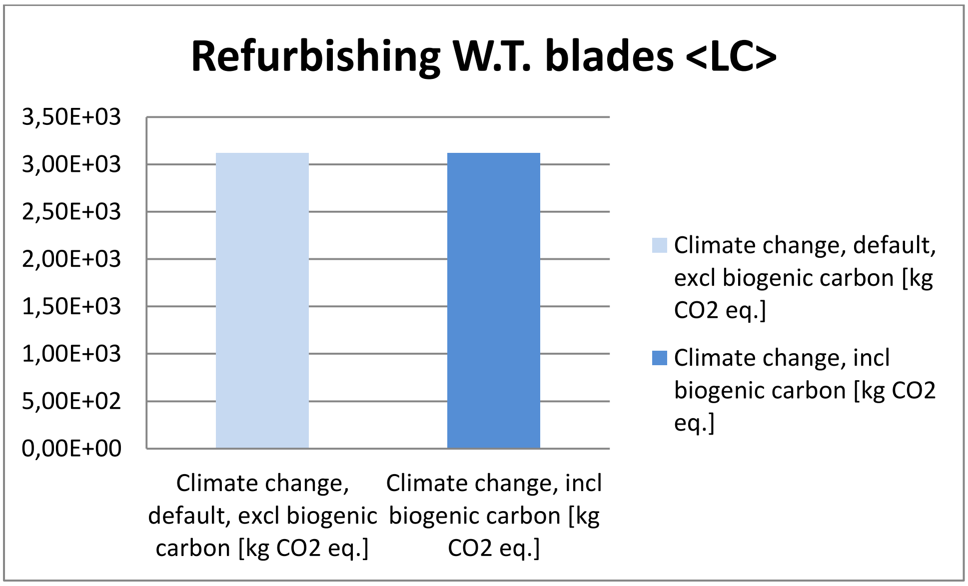


Figure 55 Graph of climate change for refurbishing of the W.T. blades application

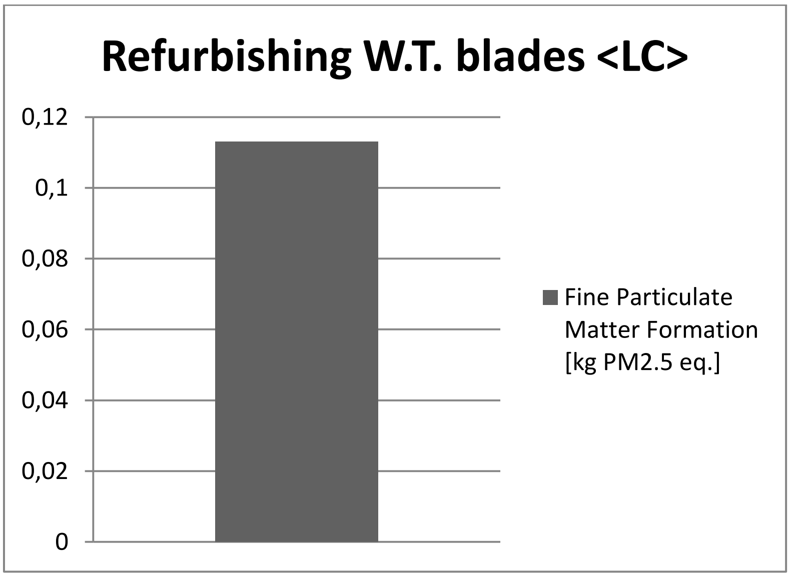


Figure 56 Graph of fine particulate matter formation for refurbishing of the W.T. blades application

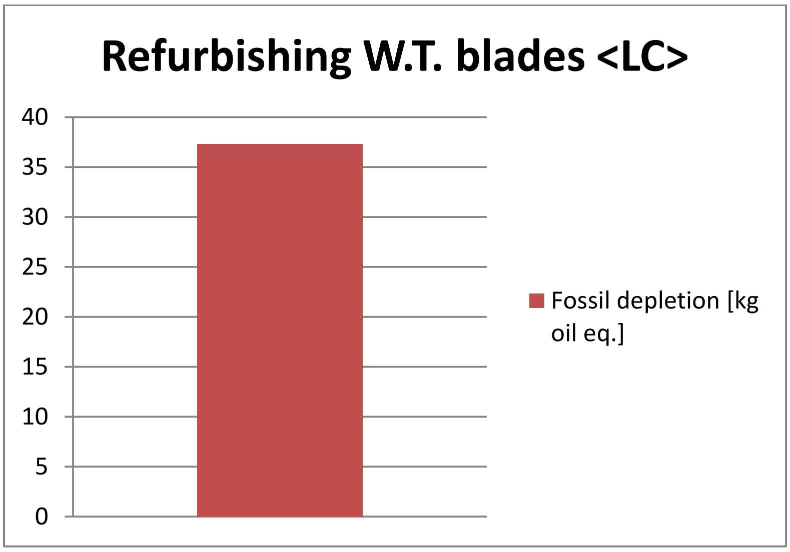


Figure 57 Graph of fossil depletion for refurbishing of the W.T blades application

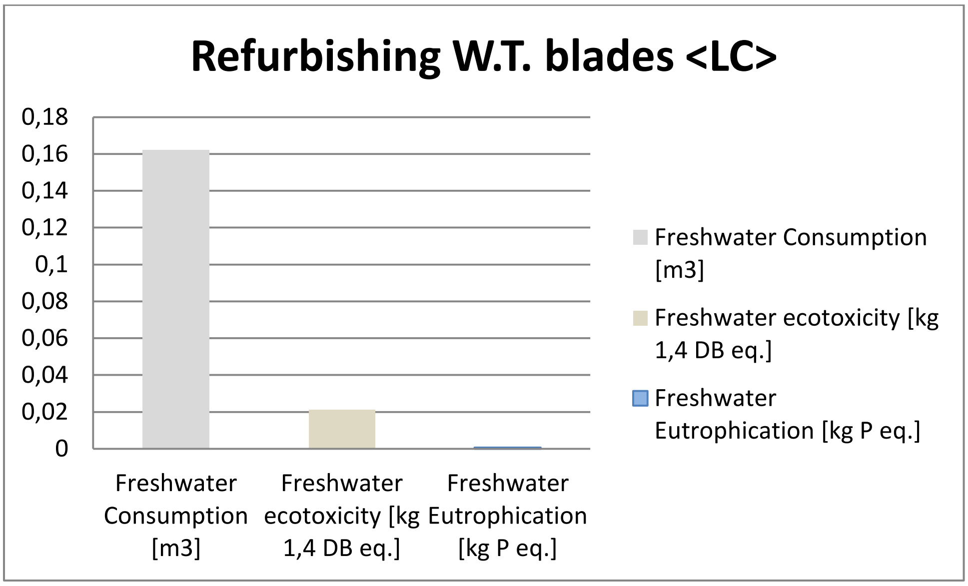


Figure 58 Graph of freshwaterconsumption, -ecotoxicity and -eutrophication for refurbishing of the W.T. blades application

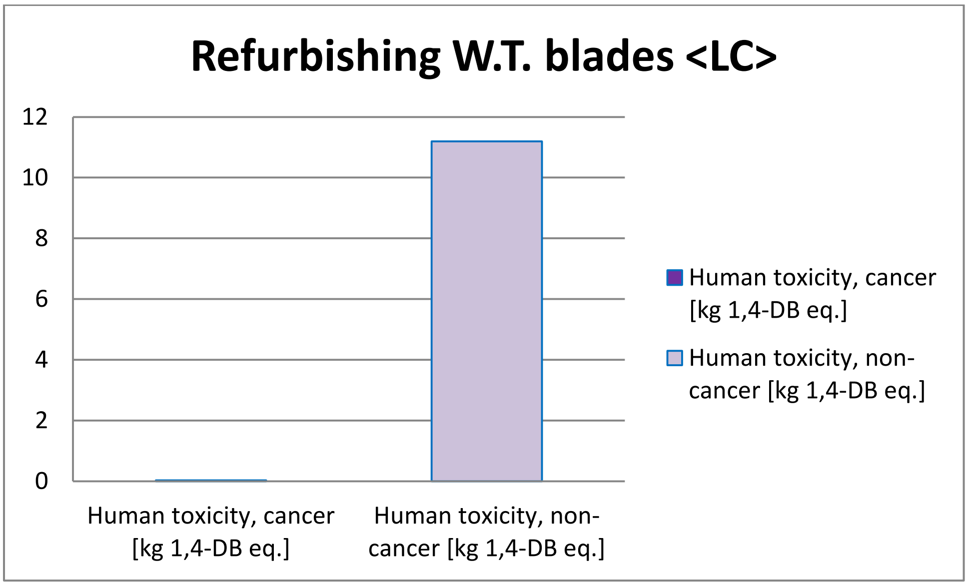


Figure 59 Graph of human toxicity (carcinogenic & non-carcinogenic) for refurbishing of the W.T. blades application

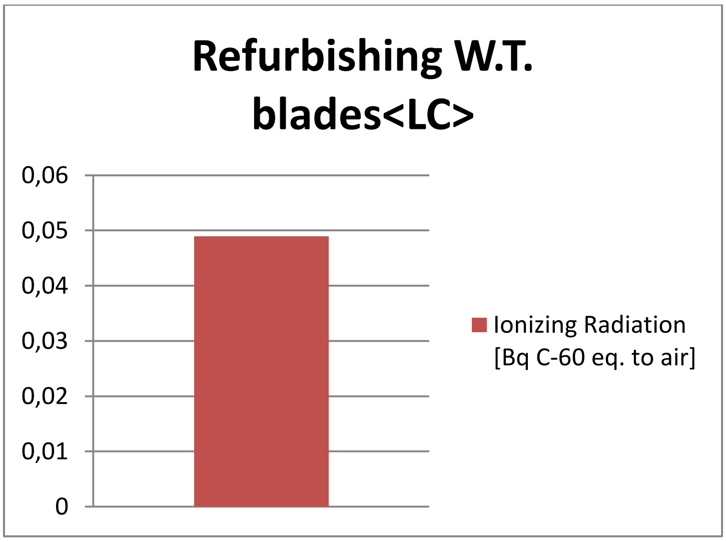


Figure 60 Graph of ionizing radiation for refurbishing of the W.T. blades application

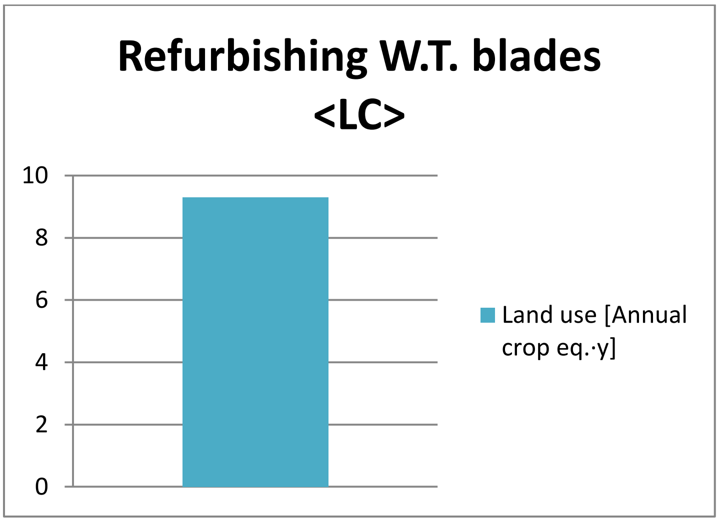


Figure 61 Graph of land use for refurbishing of the W.T. blades application

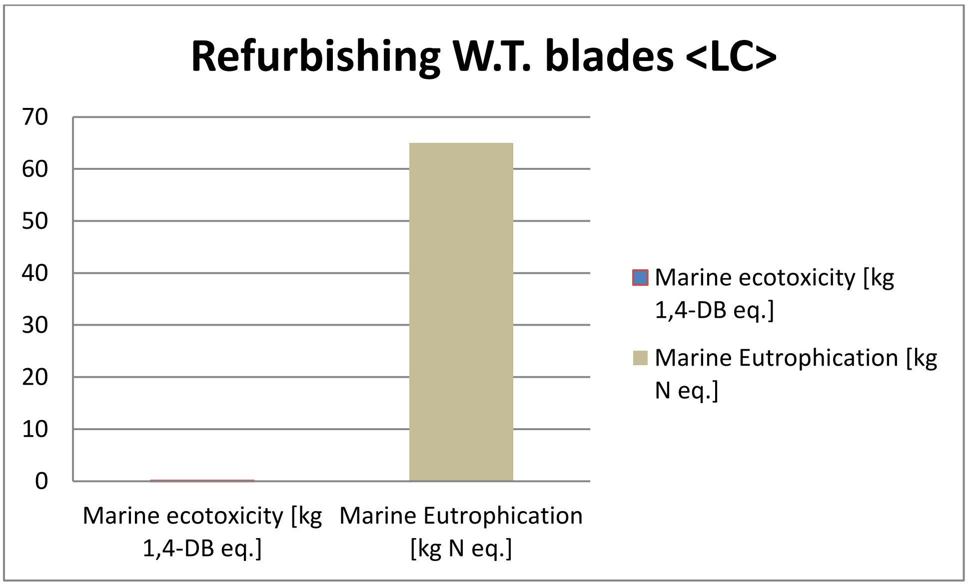


Figure 62 Graph of Marine-ecotoxicity and - eutrophication for refurbishing of the W.T. blades application

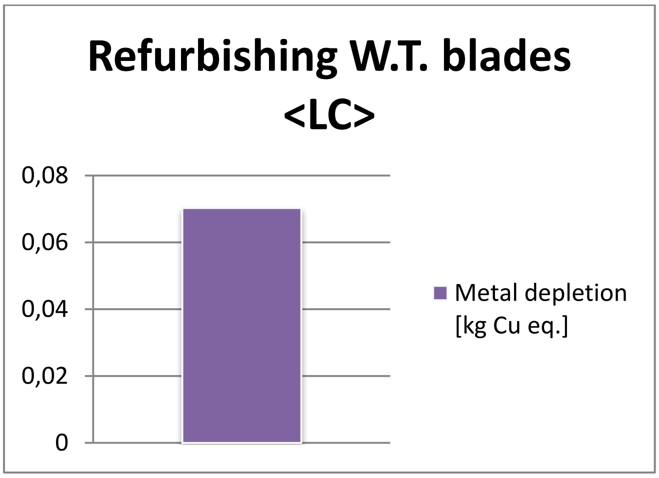


Figure 63 Graph of metal depletion for refurbishing of W.T. blades application

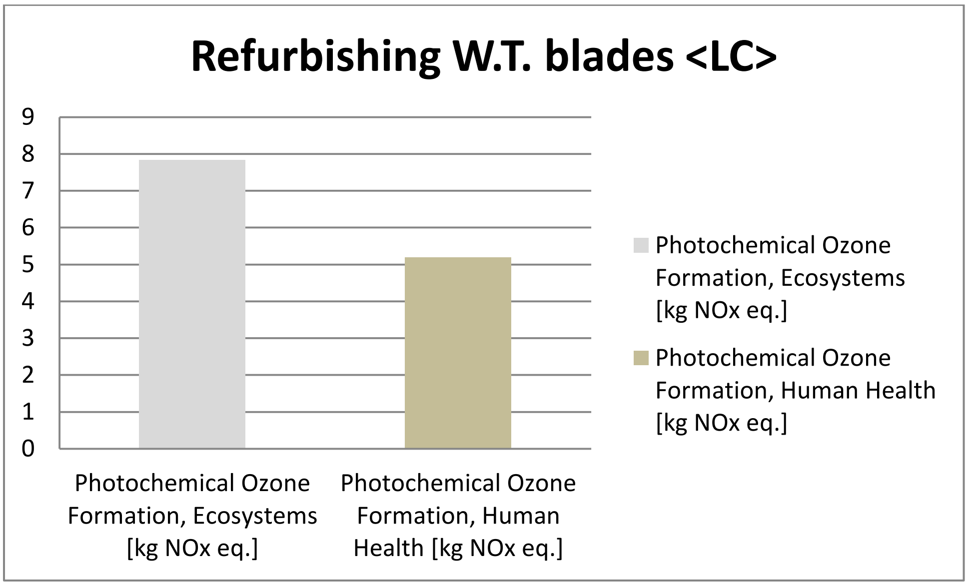


Figure 64 Graph of photochemical ozone formation ecosystems & photochemical ozone formation human for refurbishing of the W.T. blades application

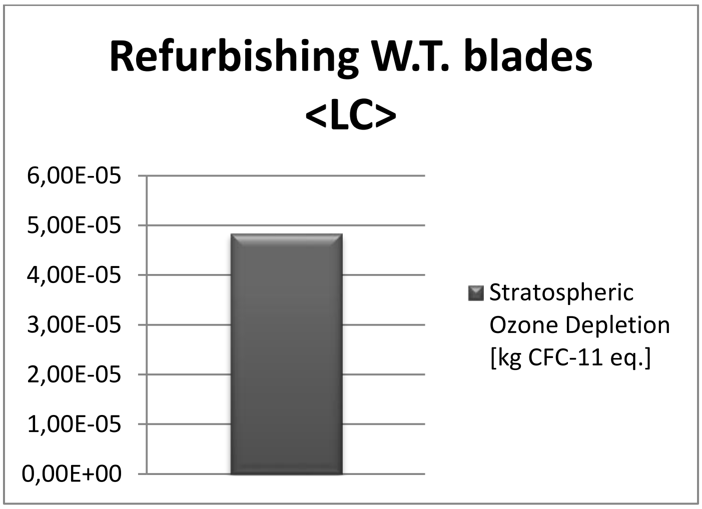


Figure 65 Graph of stratospheric ozone depletion for refurbishing of the W.T. blades application

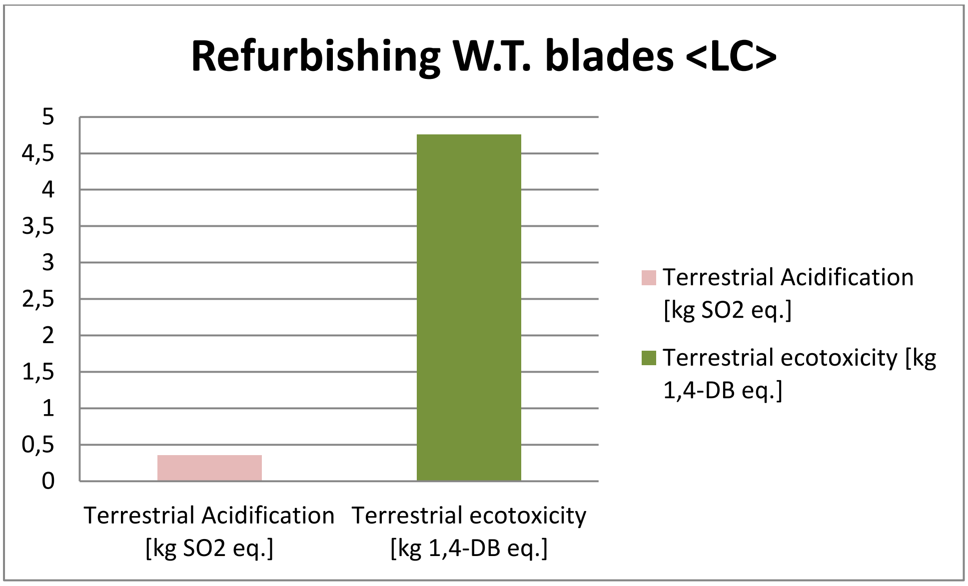


Figure 66 Graph of terrestial- acidification & -ecotoxicity for Pyrolysis of the W.T. blades application

3.1.5.4 Landfilling the W.T. blades

Landfilling of the end of life blades is the most common practiced application at the moment. This process has a linear flow and does not comply with the circular economy principle. After the blades are disassembled, they are cut and are then transported to a landfill where it will either be directly landfilled or first incinerated and landfilled afterwards.

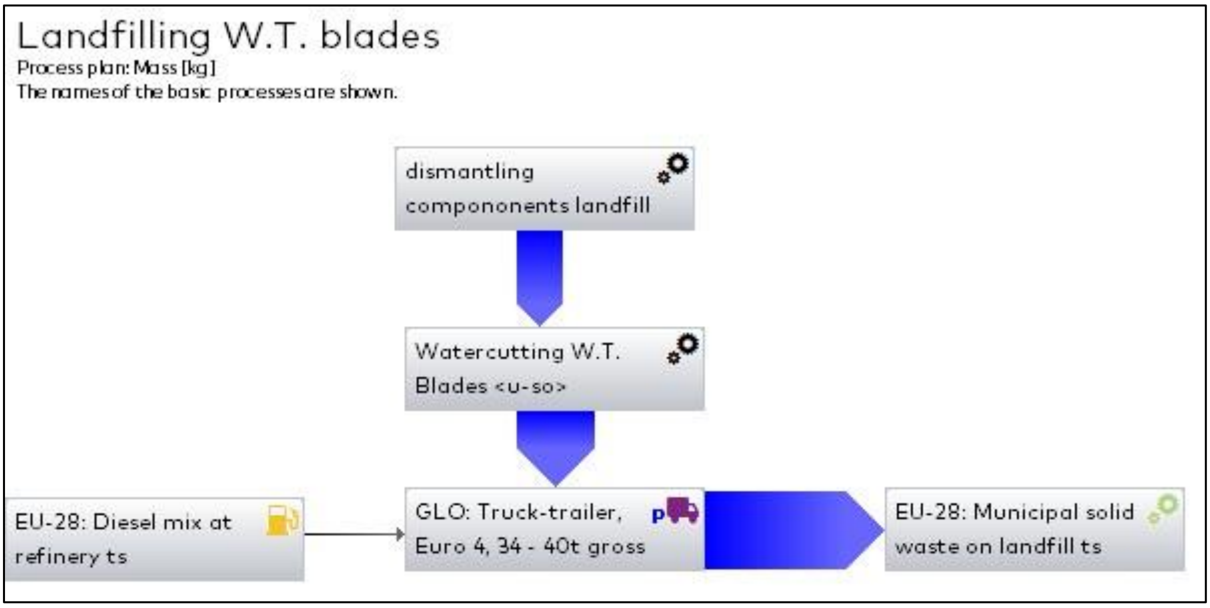


Figure 67 Process for landfilling the W.T. blades

Results for the LCA of landfilling the W.T. blades are shown below:

Landfilling W.T. blades <LC> [applied unit]	Quantity
Climate change, default, excl biogenic carbon [kg CO2 eq.]	1,00E+03
Climate change, incl biogenic carbon [kg CO2 eq.]	1,00E+03
Fine Particulate Matter Formation [kg PM2.5 eq.]	6,34E-05
Fossil depletion [kg oil eq.]	0,0213
Freshwater Consumption [m3]	0,000101
Freshwater ecotoxicity [kg 1,4 DB eq.]	2,09E-05
Freshwater Eutrophication [kg P eq.]	1,87E-05
Human toxicity, cancer [kg 1,4-DB eq.]	3,78E-05
Human toxicity, non-cancer [kg 1,4-DB eq.]	0,0029
Ionizing Radiation [Bq C-60 eq. to air]	0,000233
Land use [Annual crop eq.·y]	0,00137
Marine ecotoxicity [kg 1,4-DB eq.]	4,12E-05
Marine Eutrophication [kg N eq.]	4,65E-05
Metal depletion [kg Cu eq.]	0,00368

Landfilling W.T. blades <LC> [applied unit]	Quantity
Photochemical Ozone Formation, Ecosystems [kg NOx eq.]	0,133
Photochemical Ozone Formation, Human Health [kg NOx eq.]	0,0825
Stratospheric Ozone Depletion [kg CFC-11 eq.]	2,99E-08
Terrestrial Acidification [kg SO2 eq.]	0,000187
Terrestrial ecotoxicity [kg 1,4-DB eq.]	0,036

Table 9 Results for landfilling the W.T. blades application L.C.A.

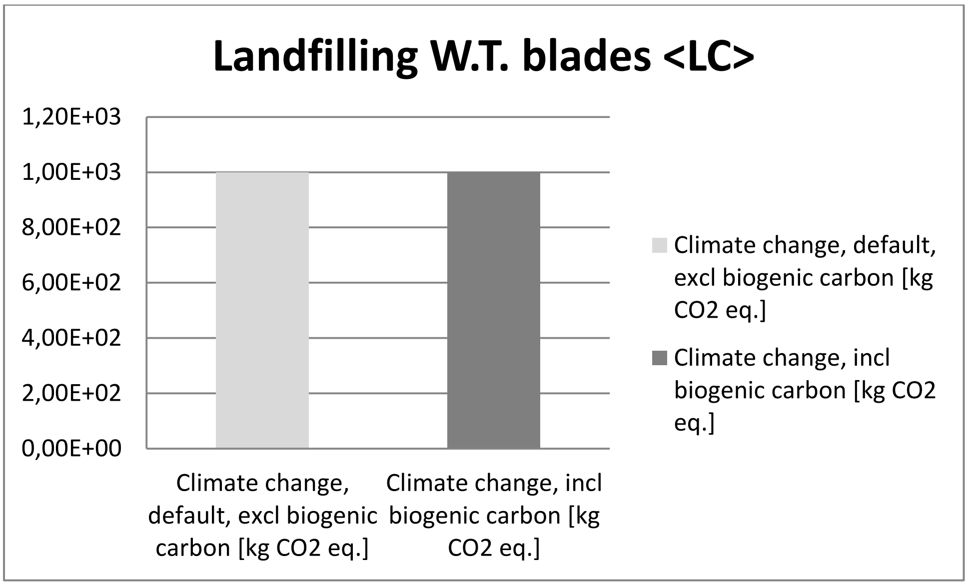


Figure 68 Graph of climate change for landfilling W.T. blades application

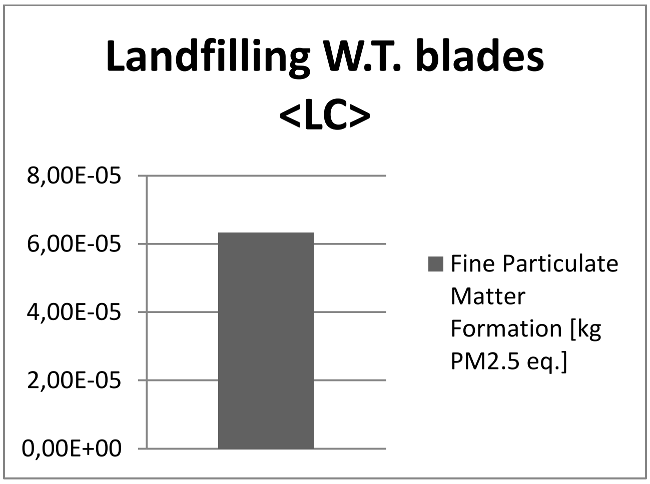


Figure 69 Graph of fine particulate matter formation for landfilling of the W.T. blades application

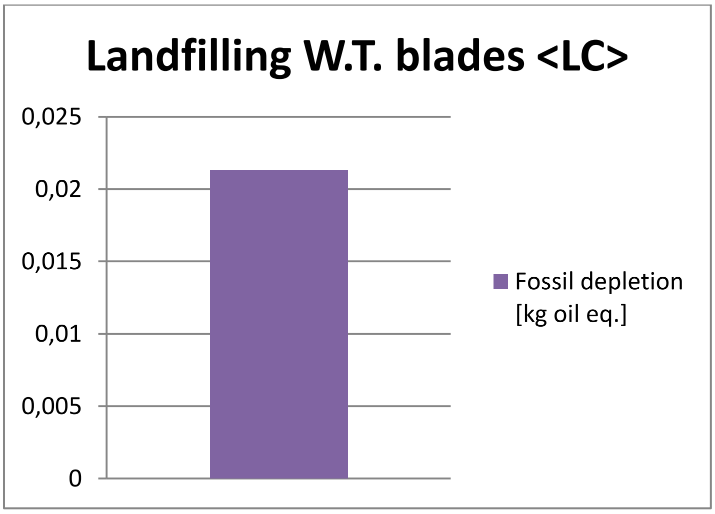


Figure 70 Graph of fossil depletion for landfilling of the W.T blades application

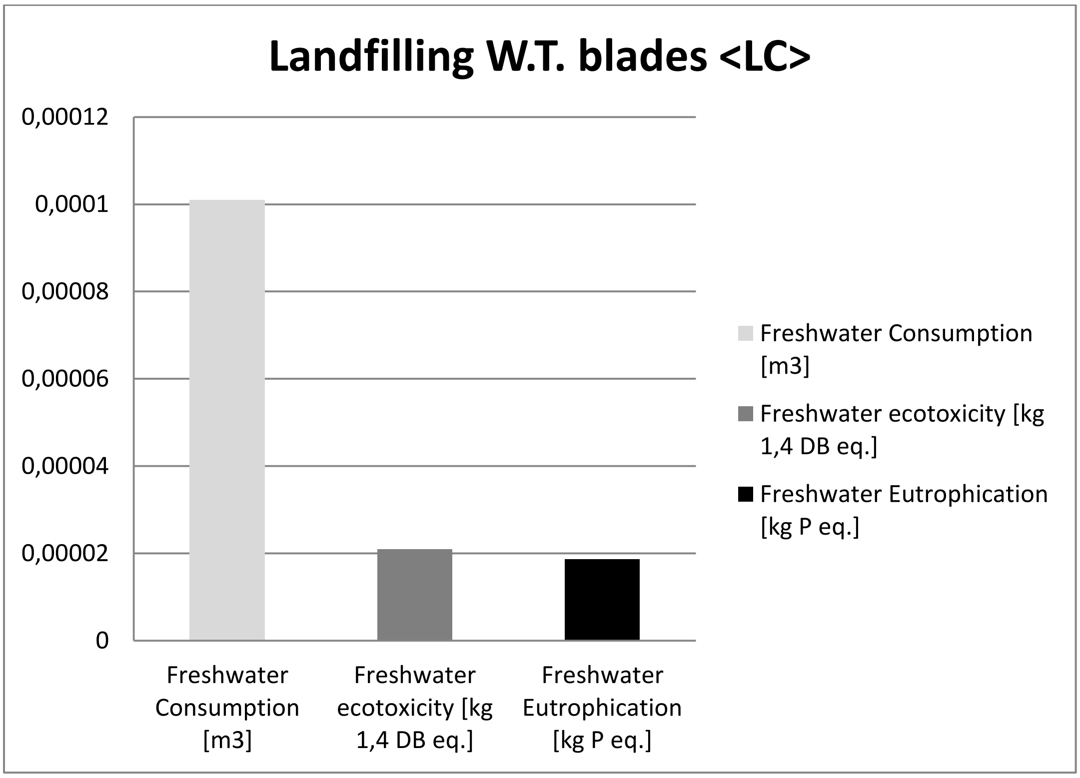


Figure 71 Graph of freshwaterconsumption, -ecotoxicity and -eutrophication for landfilling of the W.T. blades application

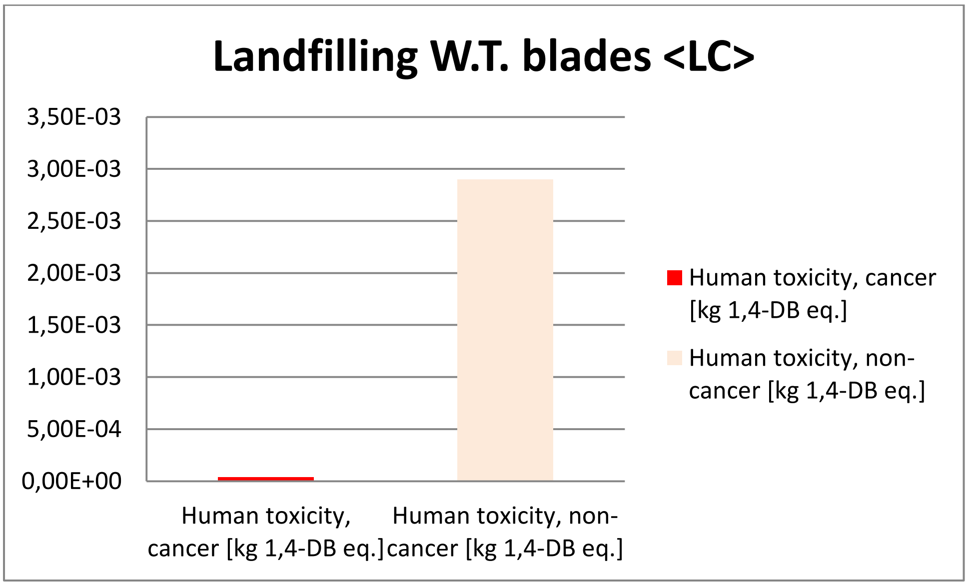


Figure 72 Graph of human toxicity (carcinogenic & non-carcinogenic) for landfilling of the W.T. blades application

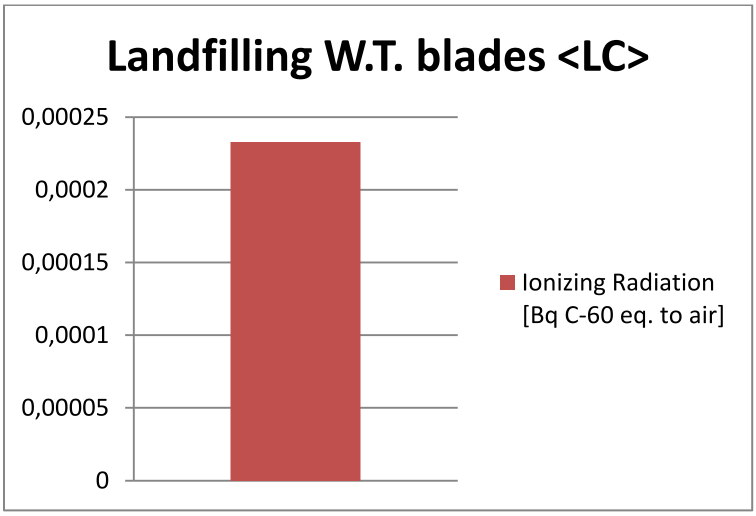


Figure 73 Graph of ionizing radiation for landfilling of the W.T. blades application

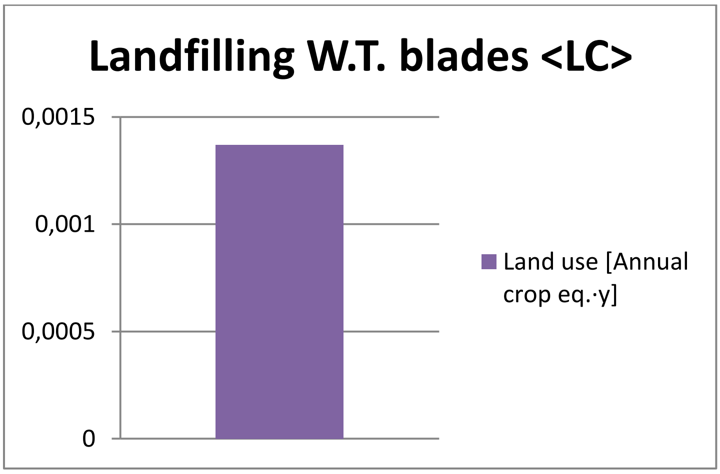


Figure 74 Graph of land use for landfilling of the W.T. blades application

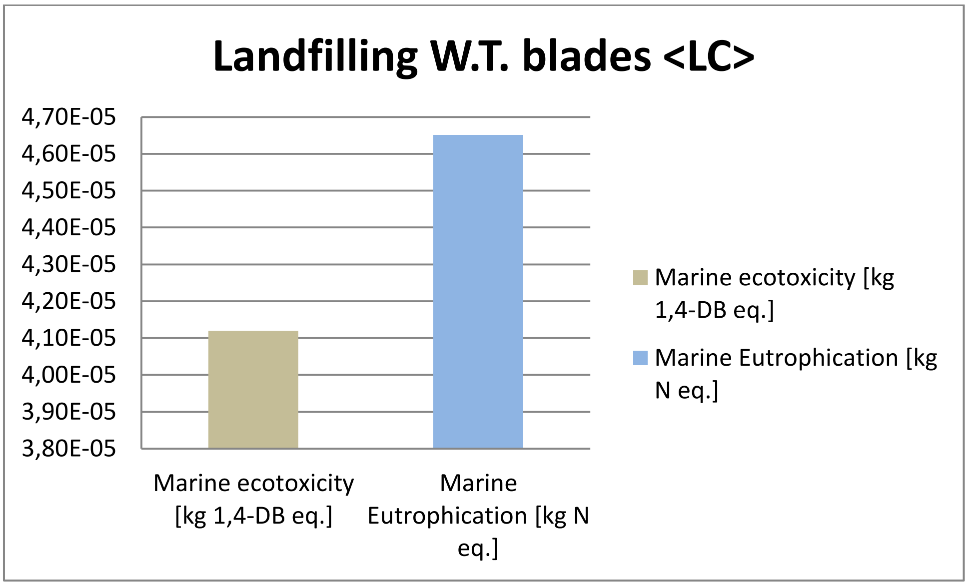


Figure 75 Graph of Marine-ecotoxicity and - eutrophication for landfilling of the W.T. blades application

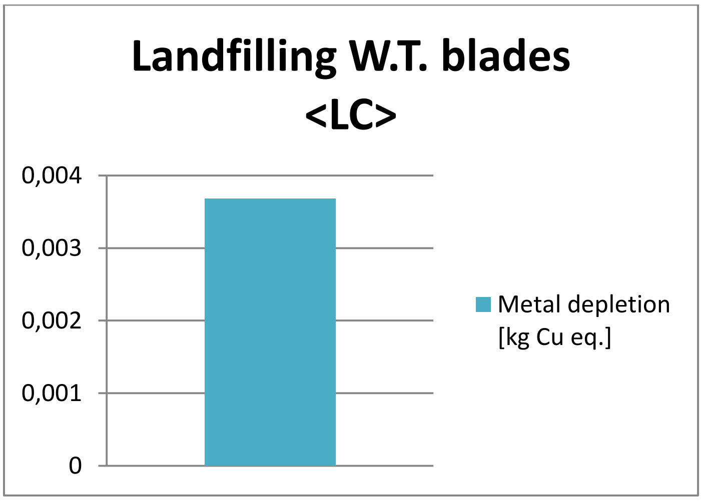


Figure 76 Graph of metal depletion for landfilling of the W.T. blades application

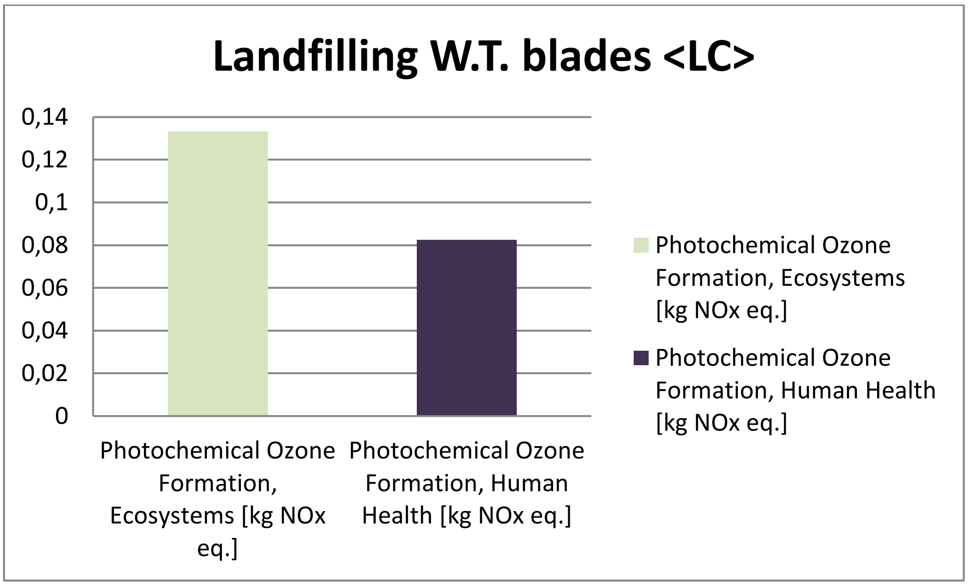


Figure 77 Graph of photochemical ozone formation ecosystems & photochemical ozone formation human for landfilling of the W.T. blades application

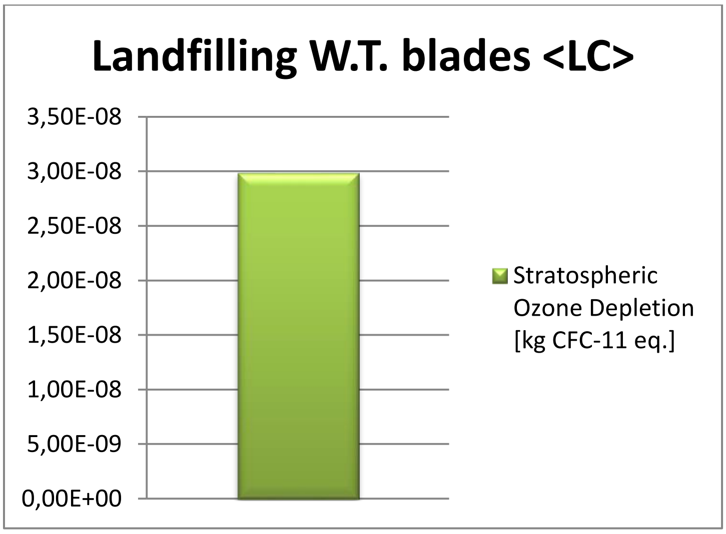


Figure 78 Graph of stratospheric ozone depletion for landfilling of the W.T. blades application

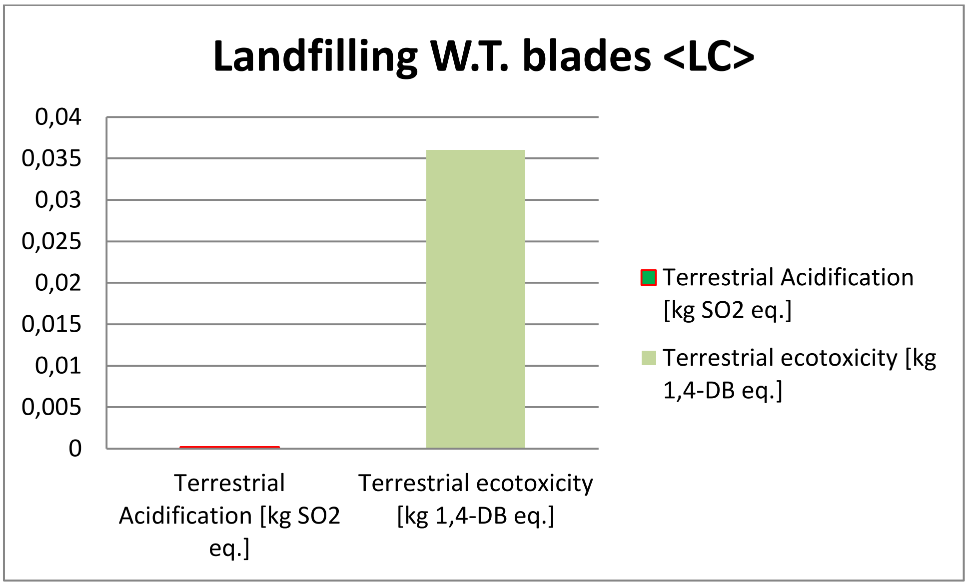


Figure 79 Graph of terrestial- acidification & -ecotoxicity for landfilling of the W.T. blades application

3.2 Business case for recycling wind turbine blades

3.2.1 Background

With the political will due to decreasing natural resources combined with geopolitical issues, renewable energy such as wind and solar Photo Voltaic energy has been rising in recent years. The rising trend of wind energy means that there will be waste after the life cycle of a wind turbine. Although most parts of the wind turbine are recyclable, the blades and the permanent magnets in the nacelle are very difficult to recycle due to the material and design of these components. Current materials used in the blades, mostly consists of epoxy and GFRP which makes the recycling complex and difficult. Since 1999 a restriction on landfilling has been enacted in the EU and a number of landfills have been closed down in recent years. This creates a dilemma, because where will the blades go when there is a limit concerning End of Life processes. Luckily there are a few options available, although some are still in its infancy and or still need to be developed for a larger scale application. Costs of manufacturing new blades is estimated to be $200.000 which is around €178.809,56 [23].

3.2.2 Issue or ambition

The main issue lays in the materials of the wind turbine blades lies in the difficulty in separating the different materials within the composite polymer matrix, which makes the recycling difficult. Most WT blades are currently landfilled or incineration due to lack of recycling applications currently available. Landfills are currently being phased out in the EU due to their policy on banning and closing landfills in attempt to encourage recycling and other sustainable practices within the concept of circular economy [12].

3.2.3 Targeted main goal

A target has been set by the EU nations at the Paris agreement to reduce the CO2 emissions by 21% in 2020. Renewable energy like wind energy is therefore one energy source in high demand due to the ideal conditions present at a number of EU countries, including the

Netherlands. The main objective is to stimulate and develop and improve current methods for recycling the wind turbine blades [18].

3.2.4 Future development in general

The development of the current and new applications looks very promising in tackling the issue with recycling the wind turbine blades. Especially using the blade material in pavements is the one to look at due to the amount of the blades which can be used for this application. Pyrolysis also looks promising, especially microwave pyrolysis can be an effective way in recycling the blades [13].

3.2.5 Specific requirements as solutions concerning the issue

Specific requirements regarding the issue in finding solutions are [12]:

- It should be sustainable
- Cheap/ financially feasible
- Easy applicable with little to no complexity to its application

3.2.6 Summary of various solutions

Here follows a summary of the various solutions connected to the business case in tackling the recycling of the wind turbine blade issue:

3.2.6.1 Refurbishing the wind turbine blades

After reaching their life cycle, wind turbines will be decommissioned. Around 20% of the blades can be refurbished, after close inspection the blades which can be repaired are selected. After selection the blades are coated, then certified and in the end sold in and outside the country and EU. This application is viable solution in reducing at least a portion of blades ending up at landfills for the time being [24].

3.2.6.2 Pyrolysis of the WT blades

Pyrolysis is a thermal process in which the blade undergoes a high temperature treatment around 500 degrees Celsius. Pyrolysis oil, filler materials for cement and paint and steam can be obtained from this process. For this process to become feasible an amount of 5000T of blade material is required [17].

3.2.6.3 Landfilling the blades

The most undesired, but the most applied application at the moment is landfilling the WT blades. As most landfills are closed down and recycling solid waste is encouraged by the government this application is also the cheapest and easiest option available [12].

3.2.6.4 Making pavements from the blades

While the blades have proven to be difficult to recycle due to the fact that it is difficult to separate each material component existing within the (GRFP) composite polymer matrix, the blades can be cut and shredded into flocks or granules. The shredded and cut material can be used in pavements, partially replacing aggregates like limestone. This would clearly limit mining of the required aggregates and would also reduce destruction of land in obtaining the aggregates [13].

This application is currently one of the most favorable as it can be applied on a large because there are a lot of pavements in Europe and the Netherlands. Another point which should be noted is that it can be used for governmental buildings and can also be used in the garden.

3.3 Further explanation of the different solutions

3.3.1 Short intro refurbishing the wind turbine blades

After decommissioning the Wind Turbine blades, these blades will be inspected. Some of the blades will be selected after going through inspection, in which the less damaged and repairable blades will be refurbished. These refurbished blades will be sold to willing buyers regionally and internationally [25].

3.3.1.1 Justification

Preventing wind turbine blades ending up at landfills is one of the main objectives in finding ways in recycling or reusing the blades. One of the options in achieving this is refurbishing wind turbine blades and then selling it to local and foreign buyers [13] & [24].

3.3.1.2 Costs

The costs for this process are estimated at € 52.801,63. A much curtailed subdivision of each cost is given in Table 10 [24].

3.3.1.3 Income

Income is estimated to be €160.317,46. See Table 11 for a much detailed calculation [23].

3.3.1.4 Feasibility

Recent market for refurbished wind turbine blades has been in decline due to decommissioning costs and fall in demand [25].

3.3.1.5 Effect on the organization

The organization or stakeholders responsible for the decommissioning, refurbishing and reselling the reusable certified wind turbine blades will be effected if the demand falls due to high costs and political decisions against this practice. If other applications like Pyrolysis and blades in pavement become feasible, policies and incentives can be created in stimulating the mentioned practices since both can effectively reduce large amount of the blades as waste on landfills.

3.3.1.6 Changing process

Refurbishing and reselling companies have been declining in recent years due to the high decommissioning costs and decline in demand for refurbished wind turbine blades [13].

3.3.2 Short intro pyrolysis of the WT blades

Pyrolysis is a thermal process, in which the blade is cut into pieces and burned at a certain degree Celsius in a furnace. The burning process produces steam, pyrolysis oil in liquid form and different solid unburnable materials which are used as fillers in cement, paint, concrete etc [17].

3.3.2.1 Justification
Although costly and energy intensive (burning fuel), pyrolysis seems to be a viable option in recycling the EoL W.T. blades [10]. Even though the quality of the material becomes less, it is still a solution which avoids the blades ending up on landfills and may become feasible with financial impulse from the government and private sector.

3.3.2.2 Costs
The initial costs are high. For this application to be breakeven, 5000 tons of EoL blades are required. Estimated costs are set at € 297.468,27. It needs to be noted that the one-off costs for the water jet cutter and pyrolysis machine have been included, see Table 11 for more detail [17].

3.3.2.3 Income
Income at the moment is relatively unknown, but the market is for pyrolysis oil and filler material is growing which is a positive development. Income is estimated around €5922,86 (Table 11).

3.3.2.4 Feasibility
Growing demand for pyrolysis oil and fillers can be profitable in the future, depending on the demand for the resources and the increasing trend of application products/processes.

3.3.2.5 Effect on the organization
Pyrolysis is one of the capital intensive processes compared to the other methods available and heavily relies on the amount of W.T. blades available to recycle. Although this process being capital intensive, especially the initial costs for the necessary equipment, Pyrolysis of the blades can be feasible and also create new jobs for current landfill workers and new in the future [13] & [17].

3.3.2.6 Changing process
Development of market demand and rising applications of resources obtained from the process has the potential in generating a matured and independent market for the products and by-products using the resources from pyrolysis [12].

3.3.3 Short intro landfilling the blades
This currently the most applied method as it is the easiest and cheapest option available. Albeit being the most applicable option for now, it is the most unsustainable and most undesired EoL practice for the amortized wind turbine blades [13].

3.3.3.1 Justification
This currently the most applied option while not being a solution in terms of recycling and circularity. The reason for this can be linked to the costs and easily accessibility of the application [12].

3.3.3.2 Costs
The costs for landfilling the blades, comes from funds derived from taxes. No concrete data is available on how much the landfilling of only the W.T. blades costs. Costs are estimated at €44.801,61 , see Table 11 for the calculated costs of each component.

3.3.3.3 Income

There is no income for this option in the Netherlands, while other EU countries charge a fee for landfilling the blades. Since no fee is required in the Netherlands the expected income is €0 (see Table 11).

3.3.3.4 Feasibility

This seems to be the cheapest option for now.

3.3.3.5 Effect on the organization

It is getting more and more difficult to landfill the EoL W.T. blades as a number of landfills have been closing down, gradually heading towards a complete ban which is already the case in Germany. Searching for alternatives is therefore a must for all the organizations involved [13] & [12].

3.3.3.6 Changing process

Gradually shifting towards total ban of landfills due to liquidation of numerous landfills, asks for a transition to a better alternative available for now or applicable in short term.

3.3.4 Short intro making pavements from the blades

The W.T. blades which are beyond repair can either be landfilled or incinerated, but there is another EoL option and that is cutting, shredding and if applicable shearing of the blades and using the produced material/aggregate in pavements. This is an effective method of avoiding the W.T. blades ending at landfills which are currently sequentially being phased out.

3.3.4.1 Justification

This is great option in reducing the blades as waste, while also adding to the positives of creating new jobs and generating income from selling the pavements.

3.3.4.2 Costs

Costs for decommissioning, transportation and equipment required to produce granulates for the pavement. Labor costs are excluded on purpose because there is no data available for these costs. It should be noted that this option is relatively new as it will we be implemented as a pilot project in 2021 in the Netherlands (Almere). The cost for producing pavements made from EoL W.T. blades is estimated to be €99.801,61 (Table 10 and Table 11).

3.3.4.3 Income

Although, no data or similar activity is available to determine or estimate an income for the application. Assumptions can be made by searching for the market and price available for glass fiber composite aggregates and price of the usual concrete or other material pavements. The income is therefore an assumption based on the price of the resources and similar final product available on the market. Income is estimated to be € 133.540,52 (Table 10 and Table 11).

3.3.4.4 Feasibility

Pavements are widely used in Europe, especially on roads and in gardens. Though this product has not been launched on the market as of yet. Little is known on the feasibility of the application. Once the product (pavement) is on the market and the market is further developed in maturity, we might know more about the feasibility of the product and process. Based on assumptions and estimates the income and costs were calculated in Table 10 and Table 11. From these tables we can assume that this application could be feasible.

3.3.4.5 Effect on the organization

The process will have a positive impact on the organizations involved in terms of environment as there will be no or less waste stream of EoL W.T. blades and creation of job opportunities. Incentives from the government are necessary to promote the process. As landfilling is discouraged and are one by one closing down, the workers at the landfills need to be relocated to find other jobs. In stimulating the pavements application new jobs can be created, a possible destination where the current landfill workers might end up. Not only new jobs can be created, but also income can be generated by selling the pavements. This somewhat fits within the circular economy concept, albeit it not being a sustainable approach. Especially when the circularity of the material flow (times the material can be recycled) is considered.

3.3.4.6 Changing process

As landfills are closing down, this option might be one of the best solutions available at the moment. Workers currently working at landfills could be shifted to this process and landfilling won't be necessary as most of the blades will be used in the pavements.

3.3.5 Activity and costs of components

In the following tables the activity and designated costs of each component is worked out. It should be noted that not all costs are included. Costs for permits, insurances and paperwork/reporting are some of the costs not included. Therefore the following tables (Table 10 Activities and the estimated costs of each component & Table 11 Costs & income balance of processes) should solely function as an indication of what the costs of each process might be.

Activity	**Quantity**	**Cost per unit (€)**	**Costs (€)**
Refurbishing W.T. Blades			
Crane	2	3000	6000
Labor	6	1333,33	8000
Truck	3	4000	12000
Coating	n.a.	26.801,63	26.801,63
	Total		52.801,63
Pyrolysis W.T. Blades			
Crane	2	3000	6000
Labor	8	1333,33	10666,64
Truck	1	4000	4000
Water Jet Cutter[1]	1	26.801,63	26.801,63

[1] One-off costs

Pyrolysis device[2]	1	250.000	250.000
	Total		297.468,27
W.T. Blades in pavement application			
Crane	2	3000	6000
Labor	6	1333,33	7999,98
Truck	1	4000	4000
Water Jet Cutter[3]	1	26.801,63	26.801,63
Shredder[4]	1	50.000	50.000
Shearer[5]	1	5000	5000
	Total		99.801,61
Landfilling W.T. Blades			
Crane	2	3000	6000
Labor	6	1333,33	7999,98
Truck	1	4000	4000
Water Jet Cutter[6]	1	26.801,63	26.801,63
Landfilling *	n.a.	0	0
	Total		44.801,61

Table 10 Activities and the estimated costs of each component

A brief elaboration of table 10 is given below.

For the refurbishing of the W.T. blades, the following is required for this process:

1. 2 Cranes for lifting and dismantling the blades and other components of the W.T. blades
2. 6 workers necessary for the dismantling, transportation and eventual refurbishing part
3. 3 trucks are required to transport each blade to the facility where it will be refurbished and certified to be resold
4. Coating equipment is also necessary to repair the blades

Pyrolysis of the W.T. blades requires the following:

1. 2 Cranes for lifting and dismantling the blades and other components of the W.T. blades
2. 6 workers necessary for the dismantling, transportation and eventual refurbishing part

[2] One-off costs
[3] One-off costs
[4] One-off costs
[5] One-off costs
[6] One-off costs
*One-off costs
n.a. => not applicable

3. A portable water jet cutting machine to cut the three blades in transportable pieces
4. One truck is necessary as the three blades are cut in such a way which makes it possible for the three blades to be transported on one truck
5. The device or machine which makes the pyrolysis process possible

Landfilling the EoL wind turbine blades has the following requirements:

1. 2 Cranes for lifting and dismantling the blades and other components of the W.T. blades
2. 6 workers necessary for the dismantling, transportation and eventual refurbishing part
3. A portable water jet cutting machine to cut the three blades in transportable pieces
4. One truck is necessary as the three blades are cut in such a way which makes it possible for the three blades to be transported on one truck

Using the W.T. blades as aggregates in pavements requires the following steps:

1. 2 Cranes for lifting and dismantling the blades and other components of the W.T. blades
2. 6 workers necessary for the dismantling, transportation and eventual refurbishing part
3. A portable water jet cutting machine to cut the three blades in transportable pieces
4. One truck is necessary as the three blades are cut in such a way which makes it possible for the three blades to be transported on one truck. The truck transports the transportable pieces to a facility
5. Once at the facility at which the cut blades will be shredded and sheared in to ideal shapes and edges with use of shredders and shearers. After the shredding and shearing the aggregates are ready to be used in the pavements

3.3.6 Balance of processes

Balance of each process is given below. The costs are highlighted in orange and the income in green. Total balance is highlighted in grey and red respectively, where red indicates that the balance has a negative value with exception of Pyrolysis of the W.T. blades.

Processes	Costs (€)*	Income (€)*	Balance (€)*
Refurbishing W.T. Blades	52.801,63	160.317,46	107.515,83
Pyrolysis W.T. Blades	297.468,27[7]	5922,86	-291.545,41
W.T. Blades in pavement application	99.801,61	133.540,52	33.738,91
Landfilling W.T. Blades	44.801,61	0	-44.801,61

Table 11 Costs & income balance of processes

[8]It should be noted that the total costs for the pyrolysis of W.T. blades process includes one-off investments in acquiring the water jet cutter and pyrolysis machine. The price for each of the one-off component is given in Table 10 and Table 11.

From all the given applications shown in Table 11, the income from refurbishing and landfilling the wind turbine blades can be found from a number of available sources.

Income for the pyrolysis application is derived from estimate prices for resources like pyrolysis oil and the remaining composite filler material for cement and paint.

For the W.T. blades in pavement application, the price of shredded and sheared granulates are calculated as estimates for the income shown in Table 11.

[7] Includes one-off investments in Water jet cutter and Pyrolysis machine
***** Estimates for 3 W.T. blades

3.3.7 Evaluation matrix of the processes

Give on the left side of the column a short name/description of each solution under "Variant"							
Status	*-- most unfavorable*	*- unfavorable*	*0 neutral*	*+ favorable*		*++ most favorable*	
Variant	Justification		Feasibility			Time dependent	
	Costs	*Income*	*Effect on organization*	*Changing process*	*Risks*	*Time/moment*	*NPV*[9]
Refurbishing the WT blades [24]	0	0	0	-	-	0	0
Pyrolysis of the WT blades [10]	-	-	-	0	-	+	0
Landfilling the blades [8]	--	--	--	--	--	--	--
Making pavements from the blades [13]	0	0	0	+	0	+	0

Table 12 Evaluation matrix of each variant

[9] Net Present Value

3.3.8 Risks of the applications

Risk of each process is given below. A detailed risk assessment is given in the S.W.O.T. analysis in Table 13 SWOT analysis of the processes.

Risks for refurbishing the WT blades are:

- Lack of resources, the amount of EoL blades needs to be guaranteed for a successful implementation
- Location of the wind farms, distance plays a vital role in acquiring the W.T. blades for an ideal price. The longer the distances, the more the added costs in making the pavements

Risks for Pyrolysis of the W.T. Blades are as follows:

- Lack of resources, the same as previous process stated. More or enough material is required for a successful and continuous application
- High investments, especially for the necessary equipment

Risks for landfilling:

- Transition to complete banishment of landfills leading to all of them being permanently closed down

Risks for wind turbine blades in pavement application are:

- Lack of resources/material available currently
- Concrete pavements are cheaper and have better properties

3.3.8.1 SWOT Analysis

Strength	Weaknesses
• There is a market for refurbished blades, resources and products obtained from available EoL processes • Systematically closing down and transitioning to a complete ban of landfills, will encourage recycling of the amortized W.T. blades	• There are limited options in recycling the blades at the moment • A number of the options are still in development phase and still need some incentives for a much broader and commercial application • Pyrolysis application is currently not feasible
Opportunities	**Threats**
• Many new techniques of recycling are being developed and studied • With amount of EoL W.T. blades to rise in the near future, Pyrolysis process might finally become feasible • Pavement application can create job opportunities, especially for the group of workers which will be affected after complete shutdown of all the landfills • The number of wind turbines is expected to rise in future, especially offshore wind farms is expected to rise exponentially. This will lead to more amortized wind turbines blades as solid waste	• Thermoplastics and other easily recyclable materials might replace the currently used unrecyclable glass fiber and epoxy composite. This will change the currently market immediately and will also have an negative impact on the suggested recycling options currently • Negative public image (sound and avian species collision) and other sustainable energy resources like solar and geothermal can negatively affect the wind energy sector as a whole in the future

Table 13 SWOT analysis of the processes

3.3.9 Advice/ Recommendations

When choosing an application for recycling the wind turbine blades one should consider the following requirements:

- The maturity of the application which adheres to adaptions necessary due to changes in the market and technology
- Feasibility of the application, a successful solution in solving an issue does not guarantee its future. The application should also be able to generate income for its operation and maintenance
- Policies and incentives promoting recycling are necessary in giving the push which is needed for investors and companies to invest in the sector. Incentives is only required until the recycling is fully functional and clearly independent

3.3.9.1 Follow up steps

More research and development for recycling applications is necessary in finding viable solutions concerning the issue. Research should be conducted in full depth in which available data and experiences of companies and other stakeholders should be critically investigated for better understanding. The acquired data and or results should be utilized in finding or developing efficient solutions.

The management and structure of dealing with waste which are not or difficult to recycled should be evaluated and if possible also be improved. A more detailed data collection for different streams of waste has room for improvements. Especially the specification of type of waste and a tracking system could be utilized.

3.4 Transportation issues

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3.4.1 Transportation

Since the 80's wind turbines went through a lot of alterations, especially when it comes to the length of the blades and the height of the tower. This rising trend length and height is expected to continue and may reach according to the IPCC a power rate of 20 MW with a rotor diameter up to 250m. In order to for this upgrade to happen, wind turbine manufacturers need to improve the design and effectively use current materials or replace them with new and or improved materials, making each component easy to repair and recycle. The blades especially need to be improved due to it being a vital component in upgrading future and bigger wind turbines. The new improved blades should be designed and developed based on their aerodynamic efficiency, its weight, statistical strength, easy to recycle and feasibility to produce them. The early wind turbine blades were smaller and were manufactured from steel, aluminum and wood. Now, glass fiber reinforced plastic (GFRP) composites are used in the ever so growing wind turbine blades. GFRP composites are ideal because it is cheap, has a good corrosion resistance and fatigue strength compared to wood and metals [5].

3.5 Discussion

The four chosen applications for recycling the W.T. blades have been analyzed through a simplified life cycle assessment via the LCA GaBi education version software. Due to the limitations of the education version, a number of the inputs and outputs were manually inserted. The amount for each input and output was derived from the available literature. Other inputs and outputs with each amount were chosen based on the similarities between the processes. The resulted graphs should therefore only be considered as an indication rather than exact scientific data. For a much more realistic view, data bases from blade manufacturers or recycling entities should be used. The simulation was done for only one unit with 3 W.T. blades.

A business case was also conducted for one wind turbine with three blades. All four processes were analyzed. Costs and calculations did not take time or period into consideration, especially considering the one off costs for the necessary equipment and the return of investments. From the business case we can conclude that landfilling does not have any financial benefits within the Netherlands and the other options should therefore be explored based on their merit and applicability.

VI Analyzing current and future solutions

The available solutions on recycling the amortized turbine blades, has shown some promise, with pyrolysis the most viable option at the moment. The other option is, using the epoxy fiber glass material as aggregates in concrete partially replacing the limestone aggregates.

Designing the blades in such a manner which makes it easy to replace parts and reverse engineer the whole blade as much as possible.

4.1 Future solutions

Due to the complexity of the problem another alternative could be a transition from a product selling to a service selling approach. In this the case the blades are not owned by the party who pays. This is not a relatively new concept of operation management or doing business. A great example is pineapple in seventeenth century Europe. Pineapple was such an exotic fruit at that time that it was not consumed but exposed to the ones who had never witnessed it before, thus functioning as a symbol of status/ recognition [26].

Decomissioning the blades and the whole process of dismantling and transporting the EOL turbine blades from windpark to the location where it will either be further processed or be landfilled is a costly burden for the party which has this responsibility. The concept of leasing instead of owning is still in its prelimenary stage as consumers still need to get used of the idea. Leasing service would be beneficial as the companies who manufacture the blades will still be the owner and thus responsible for the maintenance and decomissioning of the turbine blades. The transportation and dismantling costs can be incorporated in the total service package which would be a win win case for all parties involved. In this case the manufacterer of the turbine blades will solely be responsible for the decommission, which makes it easier as it is transparant which party is responsible.

Proposed idea is schematically given:

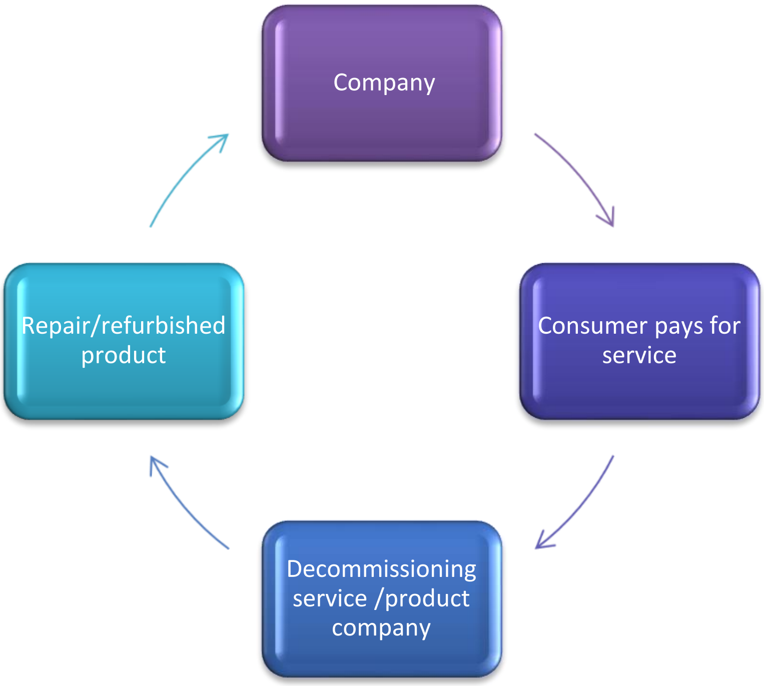


Figure 80 Proposed idea service selling approach

Explanation of the proposed schematic in Figure 80, the company sells the service/product to consumers. Consumers pay for the service/product. When the product or service is not in use due to defect or end of the terms of service the product/ blade is decommissioned by the company as the cost for decommission and transport was incorporated within the service package tariff. The product is transported to the repair/ refurbish location and from there back to the company. The refurbished blades can be sold as a new service/product, maintaining the same price which benefits the company.

4.1.1 Artificial reef

Another untried relatively new method of reusing the EoL wind turbine blades, is using it as an underwater artificial reef. This could be a viable solution for offshore wind turbines in terms of saving costs and the complexity of dismantling and transportation of large wind turbine blades. Although this method has no examples of any application and there is no clear significance data from research, it could prove to be a solution based on other artificial reef applications. From these applications and the conducted researches, the results have proven to produce some ecological advantages. Some underwater species have flourished while other species have been reduced. Therefore an EIA/analysis should be conducted before implementation of the application [27]& [28].

Figure 81 Example of artificial reef [29]

4.1.2 Replacing epoxy material with Elium resin

Epoxy is a thermoset glass fiber material which is currently very difficult to recycle as was mentioned in the previous parts of the report A number of research has been done in the past in finding other materials which can substitute the thermoset composite. One of the main criteria for this substitute material, is the recyclability. The Technological University of Delft has done some research on this matter and found that thermoplastics could be used to replace the fiberglass composite. An American company Arkem has successfully tested their thermoplastic composite material called Elium on turbine blades with the length of 8 and 25 meters respectively.

4.2 Stakeholder analysis

For the roles and responsibilities of actors or stakeholders which are vital for certain action to be taken in tackling the issue of recycling the wind turbine blades. Each stakeholder has a role to play with certain responsibilities. Stakeholders crucial for recycling the wind turbine blades in the Netherlands are given below:

- Renewable energy alternatives such as PV and Wind energy have become successful applications due to the fact that governments around world have created policies and instruments to stimulate these alternatives to fossil fuels. With regards to search for afterlife usages of the wind turbine blades, the influential governments of the EU countries such as Germany, Spain and the Netherlands have enforced policies to discourage the use of landfills. This clearly makes the government the most influential stakeholder, because with a policy and incentives they can promote/stimulate the research and development of effective technologies application which makes it possible to recycle and or reduce the amortized wind blades. The government, as an elected entity which represents the majority of the citizens has a responsibility to serve the people. Energy security is vital in this case and creating policies with instruments like incentives (feed in tariffs and subsidies), which ensures the continuity of energy production is how the government can achieve this objective. Renewable energy like Photovoltaic solar energy and wind energy have made rapid

- Companies or suppliers come into second place as they are responsible for the research and development of the wind turbine components like the blades. The material and design of the blades can be modified in order to make the recycling easier. Developing or searching for recyclable materials to replace the non-recyclable ones is also relied on the manufacturers of the blades. With the regulations and incentives put in place by the government, the companies/manufacturers are obliged and stimulated to make the necessary modifications to the wind turbine blades

- Investors can be of great importance in making investments to further develop and expand the market of the new recyclable blades. With the incentives in place and the R&D department of companies producing the necessary innovations to the blades in terms of material and design, will attract investments for financial and social gains. Financial gains can be a share in profits and social gain in getting recognition of investing in green environmental friendly energy which is good for the marketing branch of the investment groups. With wind energy being a booming industry, the demand for sustainable materials will grow. Investing in a circular economy approach, especially in a sector in which the demand of the material concerned: epoxy, can be a lucrative business opportunity for investors

- NGO's are vital as facilitators between the government and commercial entities (companies and investors). Researchers and philanthropists representing NGO's can write and initiate fundraising for awareness campaigns and research projects in finding effective ways to recycle the wind turbine blades. NGO's can also provide ideas and give feedback on new policies before implementation by the government. Research projects can also be conducted in close collaboration with the companies/ manufacturers of the wind turbine blades

- The last, but not the least we have the citizens. They choose the government and they are also major consumers of wind energy. NGO's can make the citizens aware of the issue through education and awareness campaigns. This can influence the citizens in electing a government in favor of sustainable approaches. All the aforementioned stakeholders have to please the citizens for their own designated benefits like public opinion, marketing etc.

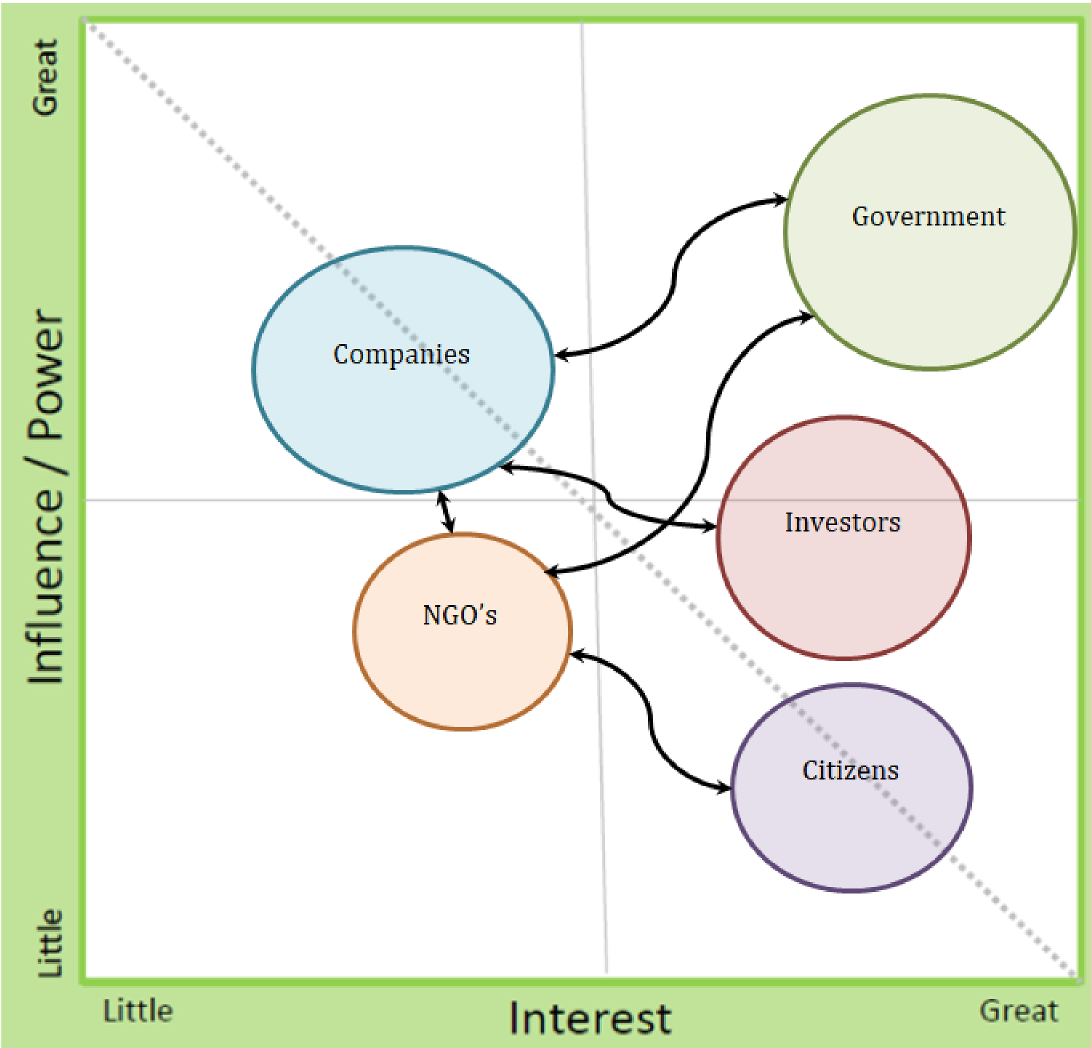


Figure 82 Roles and responsibilities between various stakeholders [30]

4.3 Policy and incentives stimulating recycling

Policies and incentives which currently do not exist yet, will be introduced and discussed in more debt with policy tree and causal field and strategy chart.

4.3.1 Policy tree

A policy tree can give you an overall view of the main objective and the categorized goals. This overall view can be used to adapt a policy during its implementation when necessary. Looking at Figure 83, the primary objective of the to be created policy is recycling the wind turbine blades. After the primary/ main objective is followed by between first goals and these are:

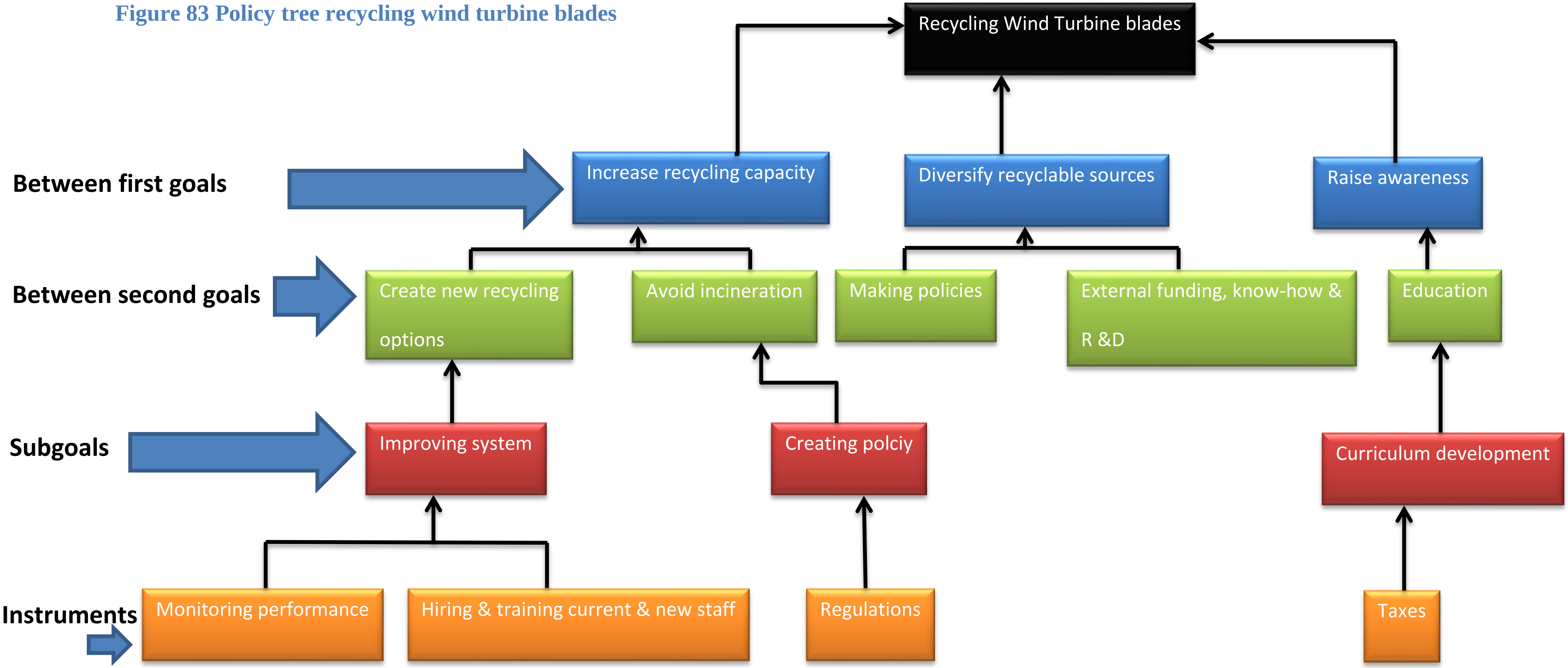
1) Increasing or improving the current recycling capacity of the wind turbine blades. Current options should be encouraged and improved while new options should be researched and developed to efficiently increase recycling. The between second goals which in support of this between first goal are:
    i) Create new recycling options, systems or methods can be developed or created for recycling the wind turbine blades through research and development. This is supported by the following sub goals:
        a) Improving the new systems through the use of training the experts and research and development. Instruments which can be applied are:
            (a) Monitoring the performance of the system. Data can be collected and used to improve the system
            (b) Hiring new staff, training the new and existing staff with the collected data and experiences from experts. Providing more insight and understanding of the system
    ii) Avoid incineration of the unrecyclable material of the blade. This is clearly not a sustainable approach and does not fit in the context of circular economy. Prohibition of incineration would stimulate recycling. In support of this between second goal is the following sub goal:
        a) Creating and enforcing a policy prohibiting incineration. Instrument supporting this sub goal:
            (a) Regulations which will be created for this policy

2) Diversify recyclable sources, another difficult to recycle source is neodymium which is part of the NdFeB (Neodymium Ferrite Boron) permanent magnet used in the wind turbines. Neodymium is a rare earth element which is largely used in computers, smartphones, electric bikes, electric vehicles etc. China is the major producer of neodymium and holds more than 95% of this market. Between 2011 and 2013 the price of neodymium and other rare earth elements skyrocketed by reaching a price of $300/kg back in 2013. Between second goals in support of the between first goal:
    i) Creating policies stimulating recycling. One is mentioned above, prohibition of incineration
    ii) External funding from the EU and foreign investors (both EU and non EU partners) as stakeholders could be used to train experts for the necessary know-

how and setting up research and development facilities where their knowledge and skills can be honed. The R & D facilities will also be utilized in developing new recyclable applications

3) Raise awareness through education programs in school. This will raise the issue to the next generation who will have to cope with the problem of dealing with EoL wind turbine blades. Educating them would at least prepare them. Followed and supported by the between second goal:
    i) Education, in order to raise awareness and prepare the next generation in dealing properly with the issue concerning the blades as waste and how to recycle them
        a) Developing a curriculum for the schools in order to educate the next generation to prepare them properly. The instrument used for this sub goal is:
            (a) Setting up taxes in order to fund the previous goals

Figure 83 Policy tree recycling wind turbine blades



4.3.2 Causal field

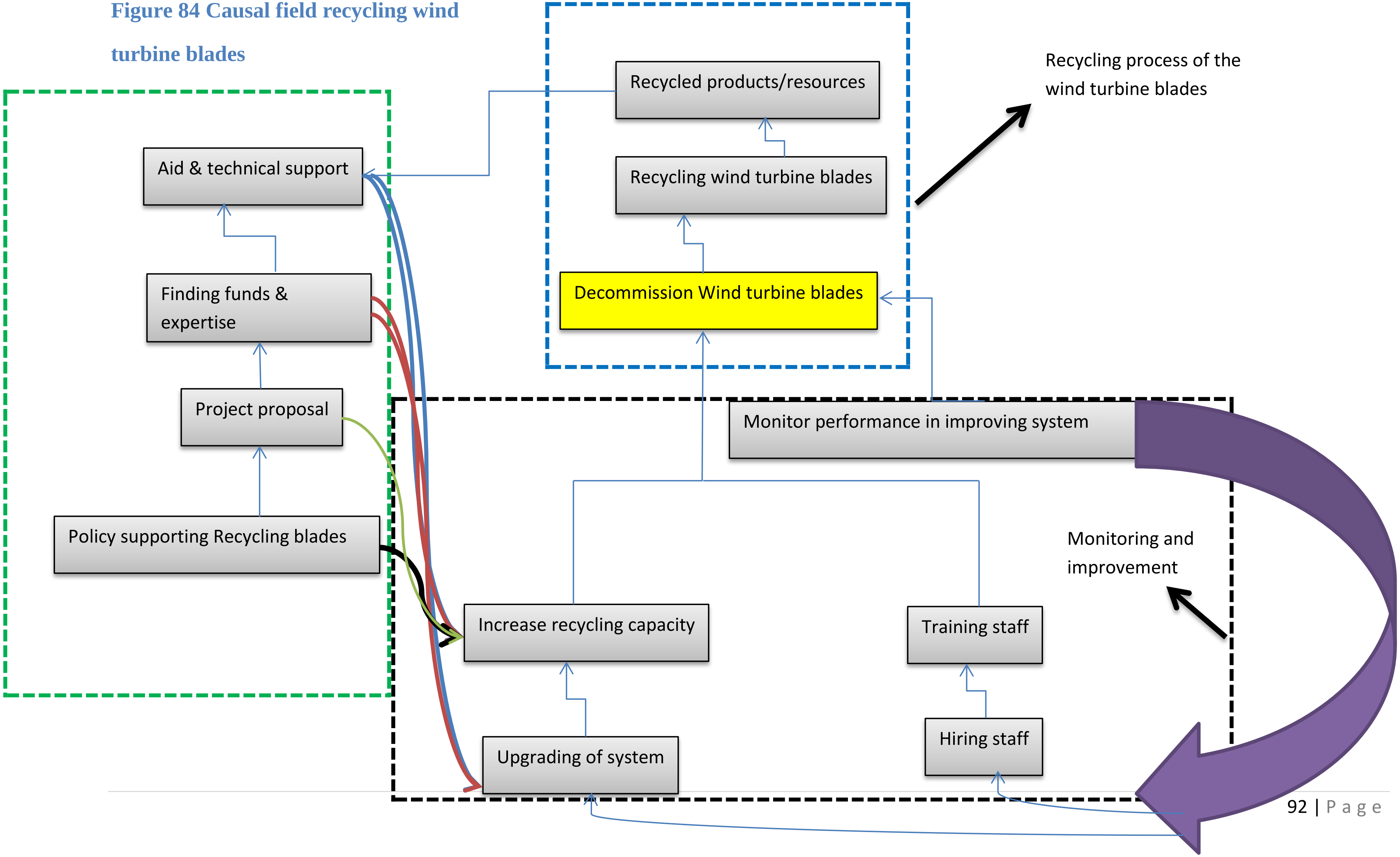
As was mentioned at the policy tree segment, the main objective is recycling the wind turbine blades. In Figure 84, the causal field of how and which actions should be taken in achieving the main purpose with the wind turbines at the center (highlighted in yellow). The causal field chart will be explained in this section. To make it easier to follow, this chart has been divided in three main parts and these are:

I. The recycling process of the wind turbine blades. Starting with the decommissioning of the wind turbine blades, highlighted in yellow. After the dismantling of each component of the wind turbine, the parts/ components will be transported to a facility where it will either be further processed to be applied to the recycling methods available or it will be landfilled. The latter is prohibited by law in the Netherlands. Followed up by the recycling processes, the product or material can be sold which can generate funding supporting the recycling process. This may play a vital role in making the whole process self-sufficient in the future.

II. Policies and instruments used for improvement. Policies should be created and utilized to promote recycling of the wind turbine blades. Supporting these policies, incentives should also be implemented. These incentives should function as stimuli for researches and projects in order to create new and improve current recycling methods. In order to find external funding and experts with the desired knowledge and skills, collaboration on regional and international level is necessary. Regional agreements and collaboration can be conducted within the EU and funding from the European Central Bank. For the international agreements and collaboration, the UN and other international organization with strong interest concerning the issue could be realized. The IMF and World Bank can be used as funding sources. External collaboration and funding do not have to be conducted within existing organizations. It can also be done in cooperation and financial support from foreign companies, having their own interest and stake.

III. Monitoring and improvement. The government alongside all the influential stakeholders should collectively find a solution on how the whole recycling process can be monitored and improved. Current and new systems can be upgraded and created with the aid of research and development and imported knowledge and skills. This can be utilized in education and projects which can be beneficial in improving the recycling system in general. Part of the utilization of education, is hiring and training new skilled and well educated workers and researchers.

Figure 84 Causal field recycling wind turbine blades



4.4 Discussion

The government is the most influential stakeholder in this situation, due to the fact it can create and enforce policies and incentives motivating the two following stakeholders (Companies and investors) to recycle the turbine blades. NGO’s can function as facilitators between the stakeholders, they can cooperate with entities which can develop or improve applications in recycling the blades. Finally the citizens are also a major stakeholder as voters, taxpayers and users of the recycled end product. Despite their minimal role and responsibility in this instance, they are important for the rest of stakeholders with each having their own stakes/ interests.

New policies should be made based on the policy tree and causal field concept provided in Figure 83 & Figure 84. Current and new policies can be adapted after review for an improved implementation. It should be noted that the aforementioned policy tree and causal field are a proposed concept and does not guarantee success. Both schematics should therefore function as a mere example of how a policy in support of recycling the W.T. blades can look like, in which there is room for improvements. For a much efficient policy and its future adaptions, concrete data is required from reliable sources. Similar or close to relatable policies can be used as benchmark on how to create and implement new policies in tackling the issues regarding the recycling of the W.T. blades.

V Conclusions and recommendations

The current technical state of the art of the afterlife application of the EoL wind turbine blades in Europe and the Globe is still in its development stage. Though limited, a few of these applications can be used currently. One of these applications is Pyrolysis in which the blade is decomposed in separate material/ resources.

Another application is shredding the wind turbine blades into granulates and using this as a resource to manufacture furniture, skateboards, decorative lamps etc. This is currently done by Demacq in the Netherlands. Replacing the thermoset epoxy material with the thermoplastic recyclable Elium is another viable option. Elium has been applied to and successfully tested blades with the lengths of 8 m and 25 m recently. There is no certainty on the performance and application of blades larger than 25 m regarding the use of Elium. Regardless of the infancy of this application, the application shows to have prominence in the near future.

The environmental impact of the afterlife applications, are some-what similar due to the fact that the following conditions apply: dismantling of the blade at location and the transportation of the blades to a location where it will be further processed or landfilled in extreme circumstances. A portion of the wind turbine blades are cut on location of dismantling, where it is transported to Vlissingen at Demacq. At Demacq the pieces of the blades are shredded into granules which are exported or sold to companies which manufacture furniture tables, decorative lamps, skateboards etc. No quantified data was available on how much of the EoL W.T. blades are recycled per annum. In Germany the blades are recycled through pyrolysis and the residue after the process is used as filler in cement.

The environmental impact of these applications has been hypothetically determined through an LCA with the software called GaBi.

The design and choice of material for the wind turbine blade is very crucial considering the rising trend of wind turbines being installed in the coming years. Wind turbine blades manufactured from recyclable material like thermoplastics and polyester can be a solution, but the mechanical and aerodynamic properties should not be compromised only because of their recyclability.

The expected environmental improvement compared to the current afterlife application of the end of life wind turbine blades, is the avoidance or at least the reduction of the blades as solid waste. Experts suggest the prevention approach as the most solvable option at the moment as it would avoid CO2 emission from transportation and incineration and would also avoid the blades to end up at the landfills as a last resort. With current development of the afterlife application of the EoL wind turbine blades, the blades can be recycled and reverse engineered in the near future. The development and recyclability of blades will create more business and job opportunities. In terms of environmental improvement the blades will not end up at landfills and incineration plants. These are the improvements which can be expected in general. For a more in depth and critical analysis of the expected environmental and economic improvement compared to the current conditions, much more data is needs to be collected.

This also accounts for the LCA, the LCA conducted for this research conducted with the educational version which has some limitations compared to the professional version. The professional version has access to more data and sources.

The afterlife usage of the blades faces a lot of challenges. Disposal at the landfill is prohibited or discouraged by law in a number of EU countries, which leaves the door open to incinerate the blades to generate energy from the heat and shred the composite material to use it as filler in cement. In order to reduce the number amortized blades new design and innovations should be applied. These alternative applications should consider the use of new recyclable materials replacing the non-recyclable ones. It should be mentioned that the new material should also be durable and withstand the various weather conditions. The blades should also be designed in a way which components or parts of the damaged blade can either be replaced or repaired.

Pyrolysis is one of the options which can be applied to recycle the turbine blades. This process decomposes the composite material into various materials which can be applied to number of different applications. Another option is to use the epoxy material as an aggregate replacing a portion of limestone in concrete applications. This application is still in its development stage, as there is no special machinery available to produce the ideal aggregates on a large commercial scale. Furthermore, much more research is necessary to investigate the water adsorption and erosion of the composite aggregate within the concrete. The amortized wind turbine blades can be reused as building materials for pedestrian bridges, emergency shelters, playground for children and more. Another option is to shred the blades and use this to manufacture furniture, skateboard and decorative lamps.

Thermoplastic can be used to replace the thermoset material (epoxy/fiberglass). A material called Elium has been developed by Arkem and so far they have been able to build 9 m and 25 m turbine blades successfully. Thermoplastics are very ductile and are ideal for the blade and it can be recycled. It is not known if Elium is already being used for blades on a commercial level and there is also no certainty if the material can be applied for much larger blades (larger than 25 meters). Nevertheless this application shows much promise for now and for the future.

A life cycle assessment was also conducted for this report with the use an LCA software GaBi. The assessment was an simulation and yield the results are provided in the designated chapter of the thesis. The results are only an indication as the education version does not have the required database for the inputs and outputs for a more realistic representation. Although data from the accumulated literature was used for the simulation and can therefore function as relatable reference on what the environmental impacts may be.

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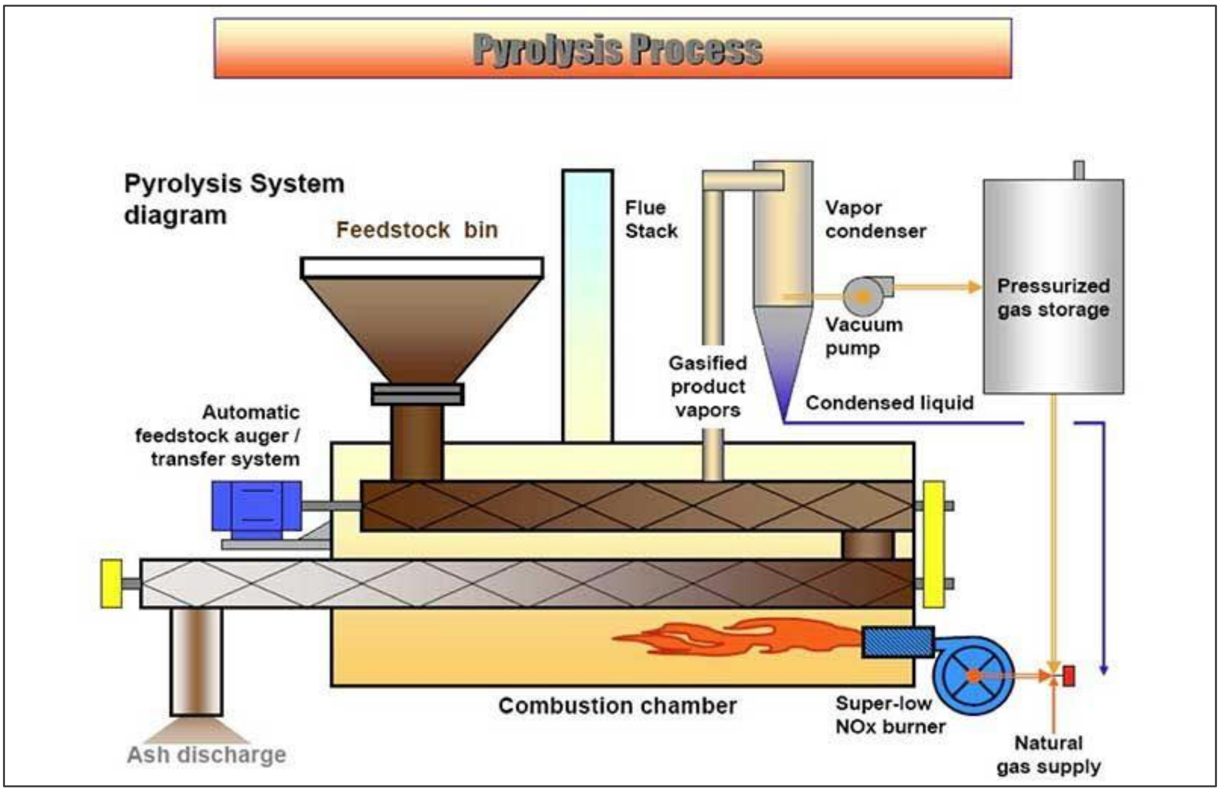
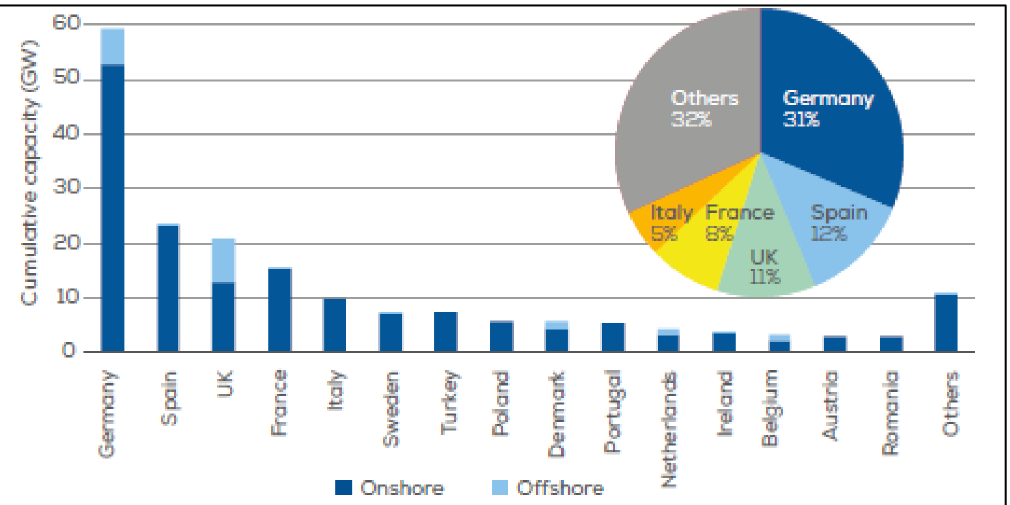
VII Appendices

Appendix I Pyrolysis process [31]



Appendix II Overview of installed onshore and offshore wind turbines in Europe [32]



Offshore	6.4	-	8.2	-	-	0.2	-	-	1.3	-	1.1	-	1.2	-	-	0.1
Onshore	52.9	23.5	12.8	15.3	10.0	7.2	7.4	5.9	4.4	5.4	3.4	3.5	2.2	3.0	3.0	10.8
Total	59.3	23.5	21.0	15.3	10.0	7.4	7.4	5.9	5.7	5.4	4.5	3.5	3.4	3.0	3.0	10.9

Source: WindEurope

II.i New installation and decommissioned wind turbines in the EU with cumulated capacity [32]

EU-28 (MW)	NEW INSTALLATIONS 2018		DECOMMISSIONED	CUMULATIVE CAPACITY 2018[5]
	ONSHORE	OFFSHORE		
Austria	230	-	29	3,045
Belgium	204	309	-	3,360
Bulgaria	-	-	-	691
Croatia	-	-	-	583
Cyprus	-	-	-	158
Czechia	14	-	-	317
Denmark	220	61	13	5,758
Estonia	-	-	-	310
Finland	0	-	3	2,041
France	1,563	2	13	15,309
Germany	2,402	969	249	59,311
Greece	207	-	15	2,844
Hungary	-	-	-	329
Ireland	193	-	-	3,564
Italy	452	-	-	9,958
Latvia	-	-	-	66
Lithuania	18	-	-	439
Luxembourg	-	-	-	120
Malta	-	-	-	-
Netherlands	166	-	72	4,471
Poland	16	-	-	5,864
Portugal	67	-	14	5,380
Romania	-	-	-	3,029
Slovakia	-	-	-	3
Slovenia	-	-	-	3
Spain	392	5	-	23,494
Sweden	717	3	13	7,407
UK	589	1,312	-	20,970
Total EU-28	7,450	2,661	421	178,826

OTHERS (MW)	NEW INSTALLATIONS 2018		DECOMMISSIONED	CUMULATIVE CAPACITY 2018[6]
	ONSHORE	OFFSHORE		
Bosnia and Herzegovina	51	-	-	51
Kosovo	32	-	-	32
Montenegro	46	-	-	118
North Macedonia	-	-	-	37
Norway	480	-	-	1,675
Russia	35	-	-	139
Serbia	356	-	-	374
Switzerland	-	-	-	75
Turkey	497	-	-	7,369
Ukraine	68	-	-	533
Total others	1,566	-	-	10,403
Total Europe	9,015	2,661	421	189,229

Appendix III Interviews

Interview with Julie Teuwen, assistant professor at the department of Aerospace Structures and Materials within the faculty of Aerospace Engineering at the TU Delft

Date: 5-06-2019 from 13:00- 13:30 PM

Topic: Thermoplastics replacing Epoxy resin in Wind turbine blade and the Erosion behavior of the current wind turbine blades

Way of contact/Medium: Skype

Question: What is the explanation of the erosion behavior of the wind turbine blades?

Answer: Erosion occurs mostly because of the rain drops while other weather conditions like hard winds, lightning, snow and temperature differences through the seasons also have some influence on the erosion of the blades. There is not much data available currently from manufacturers/suppliers and there are no tests done on the erosive behavior of the wind turbine blades. Julie has done some research regarding the issue alongside a colleague and suggested in a report that a test can be done similar to the helicopter blades being inspected on how raindrops affect the blade.

Question: Is the use of tape and paste for the eroded blades effective as a repair application? This is usually done on location, where maintenance workers are attached to a crane and repair the blades with paste and tape above ground while the blades are still attached to the hub on the tower.

Answer: No, the best way is to completely dismantle the blades and coat the surface of the blade with one or a few new layers of coating depending on the repairing methods available now. Applying tape and past to repair the edges of the blades attached to the hub is not ideal, because this is a short term solution as the tape and paste will loosen in a few months at the least.

Question: Is a thermoplastic composite resin a good substitute to the current thermoset composites used in the wind turbine blades?

Answer: Yes, the thermoplastics are elastic, thus ductile and easy to shape and mold with less use of high temperatures which saves some energy in manufacturing the blades. Another advantage of the thermoplastic resin is that it can be recycled.

Interview with Wim Robbertson from Wind in Business

Contact was made through Bettink after initially contacting Bettink first

Date: 6-06-2019 from 10:25- 10:45 PM

Topic: Decommissioning and transporting End of Life Wind turbine blades

Way of contact/Medium: Telephone/Mobile phone and email

Question: What happens to the End of Life wind turbine blades?

Answer: Around 20% of the blades can be repaired/ refurbished and then resold here in the Netherlands and to foreign countries in and outside the European continent. The rest of the blades probably goes to the landfills, incinerators and is recycled on a small scale by Demacq B.V. in Vlissingen here in the Netherlands.

Question: How are the decommissioned blades transported to destination where it will either be further processed or stored in the Netherlands?

Answer: Most of the transportation of the turbine wind blades is done by truck for onshore windfarms especially. For offshore windfarms, the transportation is mostly done by ships or a combination of ships, trains and trucks. There is no specific data available on the amount of blades transported by either truck or other transportation methods applied for the decommissioning of the wind turbine blades.

Question: Is it cheaper to transport the blades by ships, trains or a combination of both with or without trucks?

Answer: According to the interviewee not, because it is difficult to transport the blades by ships or train to the location of the windfarms (onshore) in the Netherlands. It is also difficult because of the routes and traffic on land and water, which makes it complicated to use other transport methods.

Additional data received from the interviewee: The costs for transportation and average distance from windfarm to location where the blades will be stored or further processed (incinerated or shredded/cut) was provided by the interviewee through a powerpoint presentation.

Appendix III Interviews Pondera Consult B.V.

Interview with Mogens Hinge, Phd. Chemical Engineer at the Aarhus University in Denmark

Date: 17-06-2019 from 14:10- 14:45 PM and 19-06-2019 at 14:38 PM (email)

Topic: Recycling wind turbine blades with vinegar

Way of contact/Medium: Telephone/ Mobile phone and email

Question: Based on your research and article on “Epoxy matrices Modified by Green additives for Recyclable Materials” found on your personal page of the University. How was this done and can you briefly explain this?

Answer: Based on the results of the research and what was witnessed during the experiment. Vinegar is non-toxic and not harmful for humans and environment andcan be used to decompose the layerss of the glass fiber composite. Vinegar separates the different layers of materials within the composite material, which is one of the main obstacles to recycle the epoxy material currently.

Question: I have read in a report that epoxy absorbs water, which was done in a fog room test in the US. Could this be also the reason why vinegar is able to decompose the thermoset composite?

Answer: Yes. Epoxy is known to absorb around 2-4 mass% water. This is mainly due to the large number of alcohols (and their electron lone pairs) and nitrogen (and their electron lone pairs) in the cured epoxy matrix.

But this is NOT the reason for the Acetic acid (AA) in dismantling the composite. The swelling power of water is not strong enough to break apart the epoxy matrix. But by addition of a few acid groups and disulphites to the epoxy matrix water uptake is not changed significantly (we see no difference) but the AA uptake is significant increased. Thus the AA (and the with AA following water) can generate a pressure during adsorption in a cystine modified epoxy matrix that can break it apart.

In short:
AA does not break apart unmodified epoxy matrices and water does not break apart any of the tested epoxy matrices.

Interview with Marianna Imbimbo, Pondera Consult B.V.

Date: 20-05-2019 from 13:30- 14:15 PM

Topic: Maintenance and wind classes of wind turbine

Way of contact/Medium: Personal meeting at Office in Arnhem

Question: What are the standardized windclasses of the wind turbines?

Answer: The wind turbines are divided in three main windclasses. There are other classes, but these are based on the design standards set by the manufacturers themselves. All classes are related to the wind speeds present on the site/location.

Question: How are the Wind turbines maintained and is it obligatory?

Answer: Each component of the wind turbine is inspected (visual and within the system (control monitoring) and maintained at least twice a year and yes it is obligatory. The blades are monitored,visual and by reviewing the power curve in the control system of the wind turbine, for blade erosion and repaired when the erosion has been detected.

Note: These were the relevant questions and answers which were asked and answered during the interview. There were also discussions and information provided on other aspects with no or very little relevance to the research topic.

Appendix IV Time table thesis/research report

Month	**April**				**May**				**June**				**July**				**August**			
Week	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**	**W17**	**W18**	**W19**	**W20**
Activity																				
Research preparation																				
Internship																				
Literature study																				
Submit proposal																				
Research activity																				
Data collection internship																				
Evaluate internship data/results																				
Writing activity																				
First draft thesis																				
Update draft																				
Second draft																				
Internship analysis in thesis																				
Update second draft																				
Third draft																				
Update third draft																				
Final draft thesis																				

Appendix V Numbers and locations of active Wind Turbines in the Netherlands [7]

Appendix VI Overview of total installed and decommissioned Wind Turbines [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
2-B	1	2-B Energy	6150	Het Hogeland	Groningen	02-03-2016	
A7	4	Enercon	2000	Súdwest-Fryslân	Fryslân	22-04-2009	
Adelaarsweg	2	Neg Micon	950	Zeewolde	Flevoland	18-01-2003	
Afrikahaven	2	Vestas	3000	Amsterdam	Noord-Holland	02-07-2008	
Afrikahaven	7	Vestas	3000	Amsterdam	Noord-Holland	02-07-2008	
AGP-GPC	1	Neg Micon	900	Súdwest-Fryslân	Fryslân	02-05-2005	
Aldedyk	2	Vestas	850	Súdwest-Fryslân	Fryslân	02-10-2013	
Aldedyk	2	Neg Micon	600	Súdwest-Fryslân	Fryslân	30-05-2001	01-01-2013
Alkmaarseweg 6	1	Vestas	850	Hollands Kroon	Noord-Holland	11-10-2003	
Allengaweg 1	1	Vestas	850	Súdwest-Fryslân	Fryslân	08-04-2004	
Allingawier	1	EWT	900	Súdwest-Fryslân	Fryslân	02-01-1999	
Amsterdam-Westpoort	5	Vestas	3000	Amsterdam	Noord-Holland	16-03-2007	
Andijkerwind	3	Vestas	850	Medemblik	Noord-Holland	15-11-2006	
Andorraweg	1	Lagerwey	2050	Vlissingen	Zeeland	02-07-2017	
Anna Mariapolder	16	EWT	900	Reimerswaal	Zeeland	02-09-2009	
Anna Paulowna	1	Lagerwey	80	Hollands Kroon	Noord-Holland	02-09-1995	
Anna Paulowna	1	Lagerwey	80	Hollands Kroon	Noord-Holland	02-04-1994	
Annavosdijk	5	Vestas	3000	Tholen	Zeeland	02-07-2009	
Appelvinkweg	1	Neg Micon	900	Zeewolde	Flevoland	22-03-2001	
Appelvinkweg 2-1	1	Neg Micon	1000	Zeewolde	Flevoland	27-04-2005	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Appelvinkweg 2-2	1	Neg Micon	950	Zeewolde	Flevoland	11-10-2003	
Appelvinkweg 6	1	Vestas	850	Zeewolde	Flevoland	11-02-2004	
Appelvinkweg 9	1	Vestas	850	Zeewolde	Flevoland	03-06-2004	
Arkerpad	1	Lagerwey	80	Zeewolde	Flevoland	02-02-1993	01-01-2013
Arkerpad	2	Lagerwey	80	Zeewolde	Flevoland	02-02-1995	01-01-2013
Autena	3	Nordex	3000	Vijfheerenlanden	Utrecht	02-10-2017	
Baardmeesweg 1-1	1	Neg Micon	950	Zeewolde	Flevoland	11-10-2003	
Baardmeesweg 1-2	1	Neg Micon	950	Zeewolde	Flevoland	11-10-2003	
Baardmeesweg 13	1	Vestas	660	Zeewolde	Flevoland	28-04-1999	
Baardmeesweg 17	1	Vestas	660	Zeewolde	Flevoland	29-04-1999	
Baardmeesweg 5	1	Vestas	850	Zeewolde	Flevoland	04-02-2004	
Barrepolder	4	Enercon	3000	Zoeterwoude	Zuid-Holland	02-05-2016	
Bartlehiem	2	Micon	225	Tytsjerksteradiel	Fryslân	02-01-1995	
Basal Kiesterzijl	1	Vestas	850	Waadhoeke	Fryslân	02-12-2011	
Bath	2	Vestas	660	Reimerswaal	Zeeland	24-02-2000	
Battenoert	1	EWT	900	Goeree-Overflakkee	Zuid-Holland	02-06-1996	01-01-2015
Battenoert	6	Bonus	600	Goeree-Overflakkee	Zuid-Holland	02-01-1996	01-01-2015
Battenoert	4	Enercon	3000	Goeree-Overflakkee	Zuid-Holland	12-12-2015	
Beabuorren	8	Siemens	1300	Súdwest-Fryslân	Fryslân	02-01-2007	
Bedrijventerrein Grandijk	1	Bonus	300	Noardeast-Fryslân	Fryslân	02-01-1996	

VI.i Overview of total installed and decommissioned Wind Turbines (cont.1) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Bedrijventerrein Leehove	1	Vestas	1750	Westland	Zuid-Holland	01-02-2005	01-06-2016
Bedum	1	EWT	900	Het Hogeland	Groningen	02-07-2015	
Belkmerweg 20a	1	Enercon	2300	Schagen	Noord-Holland	02-09-2017	
Belkmerweg 20a	1	Enercon	2300	Schagen	Noord-Holland	17-10-2006	01-06-2017
Belkmerweg 67	1	Enercon	2300	Schagen	Noord-Holland	02-09-2017	
Belkmerweg 67	1	Enercon	2300	Schagen	Noord-Holland	18-10-2006	01-06-2017
Bergen	1	Lagerwey	75	Bergen (NH)	Noord-Holland	02-12-1989	
Bernhardweg	6	Neg Micon	1000	Borsele	Zeeland	16-02-2008	
Bernhardweg	6	Neg Micon	1000	Middelburg	Zeeland	16-02-2008	01-10-2017
Bernhardweg C	3	Enercon	2300	Middelburg	Zeeland	01-09-2018	
Bijlweg 2	1	Neg Micon	600	Lelystad	Flevoland	20-05-1998	
Bijlweg 6	1	Neg Micon	750	Lelystad	Flevoland	15-12-2000	
Blauw	2	Enercon	800	Koggenland	Noord-Holland	10-05-2006	
Bloesemlaan	1	Neg Micon	900	Zeewolde	Flevoland	07-06-2005	
Bloesemlaan	1	Vestas	850	Zeewolde	Flevoland	26-06-2004	
Bloesemlaan	5	Neg Micon	1000	Zeewolde	Flevoland	01-10-2004	
Bloesemlaan	1	Vestas	850	Zeewolde	Flevoland	17-06-2004	
Bloesemlaan	1	Neg Micon	900	Zeewolde	Flevoland	19-06-2004	
Bloesemlaan	9	Vestas	850	Zeewolde	Flevoland	26-06-2004	
Boarnsterhim	1	Lagerwey	80	Leeuwarden	Fryslân	02-12-1994	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Boerensluisweg 5	1	Enercon	900	Hollands Kroon	Noord-Holland	01-07-2018	
Boerensluisweg 5	1	Micon	600	Hollands Kroon	Noord-Holland	17-11-1994	01-01-2018
Boerestreek 37	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	08-01-2004	
Bokum	1	Bonus	250	Het Hogeland	Groningen	02-01-1995	
Bonkelaarsdijk	1	Bonus	300	Hollands Kroon	Noord-Holland	02-01-1996	
Bornego	1	NoName	0	Heerenveen	Fryslân	02-01-1990	
Borssele	1	Vestas	600	Borsele	Zeeland	25-02-1997	01-01-2014
Bosruiterweg 30	1	Vestas	850	Zeewolde	Flevoland	03-06-2004	
Bosruiterweg 33	1	Vestas	850	Zeewolde	Flevoland	04-06-2004	
Bouwdokken	7	Enercon	4200	Veere	Zeeland	02-01-2018	
BP Amsterdam	3	Vestas	3000	Amsterdam	Noord-Holland	28-10-2005	
Bramenweg	1	Enercon	800	Meppel	Drenthe	06-10-2007	
Bredeweg 7	1	Vestas	660	Delfzijl	Groningen	11-10-2003	01-05-2016
Bredeweg 7 Bierum	1	EWT	900	Delfzijl	Groningen	02-06-2016	
Bredyk	1	Bonus	300	Leeuwarden	Fryslân	02-01-1996	
Brekkerweg 6	1	Neg Micon	900	Súdwest-Fryslân	Fryslân	02-09-2005	
Britsum	1	Bonus	300	Leeuwarden	Fryslân	02-01-1996	
Brongersmaweg 2	1	Bonus	600	Noardeast-Fryslân	Fryslân	02-01-1997	
Buorren	3	Vestas	850	Súdwest-Fryslân	Fryslân	01-10-2003	
Buorren	1	Vestas	850	Súdwest-Fryslân	Fryslân	06-06-2007	

VI.ii Overview of total installed and decommissioned Wind Turbines (cont.2) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Buorren	2	Vestas	850	Súdwest-Fryslân	Fryslân	25-03-2006	
Buren	4	Vestas	2000	Buren	Gelderland	02-08-2014	
Burgerveen	2	Enercon	2300	Haarlemmermeer	Noord-Holland	02-05-2015	
Burgerveen-Oost	1	Micon	250	Haarlemmermeer	Noord-Holland	07-12-1993	
Burgerveen-Oost	1	Enercon	2300	Haarlemmermeer	Noord-Holland	31-03-2012	
Burgerveen-Oost	2	Enercon	800	Haarlemmermeer	Noord-Holland	31-03-2012	
Burgervlotbrug	9	Vestas	850	Schagen	Noord-Holland	11-07-2009	
Carl Fellingerwei	3	Neg Micon	900	Súdwest-Fryslân	Fryslân	02-06-2005	
Clothildis	6	Nordex	800	Hoeksche Waard	Zuid-Holland	02-01-1999	
Coevorden	1	Vestas	3300	Coevorden	Drenthe	02-09-2015	
Creilerpad	1	Tacke	600	Noordoostpolder	Flevoland	02-01-1995	
Culemborg	3	Vestas	2000	Culemborg	Gelderland	27-01-2006	
Curiestraat	1	Enercon	2000	Harlingen	Fryslân	15-05-2004	
Dantumadiel	1	Lagerwey	80	Dantumadiel	Fryslân	02-04-1993	
Dantumadiel	1	Lagerwey	75	Dantumadiel	Fryslân	02-07-1996	
De Ambtenaar	1	Enercon	7500	Hollands Kroon	Noord-Holland	02-05-2012	
De Bjirmen	12	Nordtank	500	Waadhoeke	Fryslân	16-12-1995	
De Boomgaard	2	Lagerwey	80	Veere	Zeeland	02-08-1992	01-12-2016
De Gaest	2	Neg Micon	750	Súdwest-Fryslân	Fryslân	02-07-2004	
De Haagse Molen	1	Vestas	3300	s-Gravenhage	Zuid-Holland	02-12-2016	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
De Horn	6	Enercon	800	Medemblik	Noord-Holland	06-07-2005	01-05-2018
De Houwen 3	1	Vestas	850	Noardeast-Fryslân	Fryslân	08-12-2004	
De Kroeten	1	Vestas	850	Breda	Noord-Brabant	05-06-2004	
De Leane 3	1	Neg Micon	900	Súdwest-Fryslân	Fryslân	03-03-2006	
De Locht kerkrade	2	Nordex	2500	Kerkrade	Limburg	02-01-2006	01-03-2016
De Marne	1	Siemens	1300	Het Hogeland	Groningen	02-01-2000	
De Mars	3	Enercon	2050	Zutphen	Gelderland	08-12-2005	
De Nes	2	Enercon	2300	Waterland	Noord-Holland	01-01-2012	
De Rijp Friesland	1	NoName	0	Noardeast-Fryslân	Fryslân	02-01-1995	
De Ruil 6	1	Vestas	850	Medemblik	Noord-Holland	15-12-2004	01-06-2017
De Ruil 6	1	Enercon	800	Medemblik	Noord-Holland	02-09-2017	
De Slachte 6	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	18-10-2005	
De Trompet	1	Vestas	2000	Heemskerk	Noord-Holland	21-12-2005	
De Volhouder	1	Lagerwey	75	Bergen op Zoom	Noord-Brabant	02-04-1991	
De Windroos	1	Enercon	2000	Dronten	Flevoland	06-04-2004	
De Windvogel	1	Neg Micon	950	Zeewolde	Flevoland	04-03-2004	
De Windvogel	1	Enercon	600	Gouda	Zuid-Holland	02-01-1998	
De Windvogel	1	Enercon	2050	Ouder-Amstel	Noord-Holland	08-12-2005	
De Windvogel	1	Lagerwey	80	Bodegraven-Reeuwijk	Zuid-Holland	02-04-1994	
De Windvogel	1	Neg Micon	900	Zeewolde	Flevoland	18-10-2005	

VI.iii Overview of total installed and decommissioned Wind Turbines (cont.3) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
De Wiske	1	Bonus	300	Waadhoeke	Fryslân	02-01-1995	
Defensie Coevorden	3	Vestas	3000	Coevorden	Drenthe	02-11-2011	
Delfzijl Noord	19	Nordex	3300	Delfzijl	Groningen	02-08-2015	
Delfzijl Zuid	10	Enercon	2300	Delfzijl	Groningen	06-09-2008	
Delfzijl Zuid	8	Enercon	2050	Delfzijl	Groningen	19-10-2006	
Delfzijl Zuid	10	Enercon	2300	Delfzijl	Groningen	19-10-2006	
Delfzijl Zuid	6	Enercon	2050	Delfzijl	Groningen	06-09-2008	
Deltawind	1	Lagerwey	80	Goeree-Overflakkee	Zuid-Holland	02-02-1993	01-01-2016
Deltawind	1	Lagerwey	75	Goeree-Overflakkee	Zuid-Holland	02-12-1990	01-01-2016
Deltawind	1	Lagerwey	80	Goeree-Overflakkee	Zuid-Holland	02-02-1993	01-11-2016
Den Oever	1	Vestas	600	Hollands Kroon	Noord-Holland	26-07-1997	
Derde Dijk	1	Enercon	2000	Tholen	Zeeland	02-09-2015	
Dijksterbuurtlaan 1	1	Vestas	850	Súdwest-Fryslân	Fryslân	15-05-2003	
Dintel SurveyCom	3	Enercon	3000	Steenbergen	Noord-Brabant	02-10-2016	
Dintelhaven	5	Vestas	3000	Rotterdam	Zuid-Holland	14-01-2006	
Dinteloord	4	Vestas	600	Steenbergen	Noord-Brabant	24-12-1998	
Diodeweg	2	Vestas	225	Hoorn	Noord-Holland	12-05-1999	01-01-2013
Distridam	5	Vestas	2000	Rotterdam	Zuid-Holland	24-12-2005	01-01-2013
Distridam	2	Nordex	2500	Rotterdam	Zuid-Holland	02-01-2006	01-01-2013
Distripark	4	Vestas	3000	Waddinxveen	Zuid-Holland	20-12-2006	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Dobbelstenen	2	Neg Micon	2750	Rotterdam	Zuid-Holland	02-04-2005	01-01-2013
Dodaarsweg	11	Vestas	850	Zeewolde	Flevoland	29-04-2003	
Dodaarsweg	1	Lagerwey	80	Zeewolde	Flevoland	02-02-1993	
Dodaarsweg	11	Vestas	850	Zeewolde	Flevoland	29-06-2002	
Dongeradeel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-06-1993	
Dongeradeel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-06-1992	
Dongeradeel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-11-1994	
Dongeradeel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-06-1993	
Dongeradeel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-07-1995	
Dongeradeel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-01-1995	
Dongeradeel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-04-1992	
Dongeradeel	1	Lagerwey	75	Noardeast-Fryslân	Fryslân	02-06-1989	
Dongjummerweg 5	1	Nordtank	300	Waadhoeke	Fryslân	20-11-1999	
Doniaburen 2	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	08-01-2004	
Dorpsmolen Skuzum	1	Micon	225	Súdwest-Fryslân	Fryslân	19-09-1996	
Dorpsmolen. Reduzum	1	Micon	225	Leeuwarden	Fryslân	20-10-1994	
Drechterland	1	EWT	900	Drechterland	Noord-Holland	02-08-2013	
Dreischor	4	Vestas	225	Schouwen-Duiveland	Zeeland	26-06-1996	01-04-2016
Drielsedijk 19a	1	NedWind	100	Arnhem	Gelderland	02-01-1995	01-06-2016
Drietorensweg 6-1	1	Vestas	225	Noordoostpolder	Flevoland	26-01-1995	

VI.iv Overview of total installed and decommissioned Wind Turbines (cont.4) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Drietorensweg 6-2	1	Vestas	225	Noordoostpolder	Flevoland	26-01-1995	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-05-1995	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-08-1993	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-01-1996	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-10-1995	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-09-1993	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-10-1995	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-05-1995	
Dronten	1	Lagerwey	80	Dronten	Flevoland	02-03-1993	
Duikerweg	1	Lagerwey	80	Zeewolde	Flevoland	02-06-1995	
Duikerweg	1	Lagerwey	80	Zeewolde	Flevoland	02-02-1993	
Duikerweg 06	1	Vestas	660	Zeewolde	Flevoland	26-05-2002	
Duikerweg 38	1	Vestas	850	Zeewolde	Flevoland	30-09-2003	
Duikerweg 42	1	Vestas	850	Zeewolde	Flevoland	11-03-2004	
Duikerweg 46	1	Neg Micon	900	Zeewolde	Flevoland	25-05-2004	
Duinvogel	1	WindMaster	750	s-Gravenhage	Zuid-Holland	02-01-1999	01-01-2014
Duiven	4	Vestas	2000	Duiven	Gelderland	02-08-2014	
Dwarsweg 38	1	Vestas	850	Het Hogeland	Groningen	04-03-2004	
Dyksterhuzen 1	1	Bonus	300	Waadhoeke	Fryslân	02-01-1996	
Echteld	4	Enercon	2000	Neder-Betuwe	Gelderland	01-11-2008	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
ECN Petten	1	NedWind	250	Schagen	Noord-Holland	02-01-1995	
ECN Testpark	1	NoName	0	Hollands Kroon	Noord-Holland	16-03-2017	01-07-2018
ECN Testpark	1	Siemens	3600	Hollands Kroon	Noord-Holland	02-01-2006	31-12-2018
ECN Testpark	1	Darwind	5000	Hollands Kroon	Noord-Holland	02-07-2011	
ECN Testpark	1	Siemens	3000	Hollands Kroon	Noord-Holland	02-03-2013	31-12-2015
ECN Testpark	1	GE Wind	2500	Hollands Kroon	Noord-Holland	02-10-2013	31-12-2018
ECN Testpark	1	GE Wind	3200	Hollands Kroon	Noord-Holland	02-01-2016	31-12-2018
ECN Testpark	1	Siemens	2300	Hollands Kroon	Noord-Holland	02-01-2012	01-06-2015
ECN Testpark	1	GE Wind	3230	Hollands Kroon	Noord-Holland	11-05-2016	31-12-2018
ECN Testpark	1	Alstom	2700	Hollands Kroon	Noord-Holland	08-10-2013	01-06-2017
ECN Testpark	5	Nordex	2500	Hollands Kroon	Noord-Holland	02-01-2003	01-07-2018
Ecopark Waalwijk	5	GE Wind	1500	Waalwijk	Noord-Brabant	02-08-2005	
Ede	1	NoName	0	Ede	Gelderland	02-01-1999	
Ede	1	NoName	0	Ede	Gelderland	02-01-2000	
Eemsmond	1	Bonus	600	Het Hogeland	Groningen	02-01-1996	01-01-2015
Eemswouderlaan 10	1	Vestas	850	Súdwest-Fryslân	Fryslân	12-02-2004	
Eemswouderlaan 12	1	Vestas	850	Súdwest-Fryslân	Fryslân	15-12-2005	
Egmond aan Zee	36	Vestas	3000	Offshore	Offshore	02-12-2006	
Egmondstraat	2	Enercon	900	Waadhoeke	Fryslân	02-09-2017	
Egmondstraat	2	Neg Micon	950	Waadhoeke	Fryslân	09-04-2004	01-03-2017

VI.v Overview of total installed and decommissioned Wind Turbines (cont.5) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Elandweg 81	1	Neg Micon	750	Lelystad	Flevoland	16-09-2000	
Elho	1	Nordex	2500	Tilburg	Noord-Brabant	16-07-2016	
Emmaweg 30	1	Vestas	850	Het Hogeland	Groningen	19-08-2005	
ENCI	1	Vestas	2000	Rotterdam	Zuid-Holland	02-07-2007	
Eppenhuizerweg	1	Vestas	850	Het Hogeland	Groningen	02-10-2011	
Eppenhuizerweg 33	1	Bonus	300	Het Hogeland	Groningen	02-01-1996	01-01-2011
EPZ	3	Neg Micon	2750	Borsele	Zeeland	23-12-2004	
EPZ	2	Senvion	6150	Borsele	Zeeland	08-06-2012	
EPZ	1	Neg Micon	750	Borsele	Zeeland	23-12-2004	
EPZ	1	Neg Micon	2750	Borsele	Zeeland	23-12-2004	
Espelerringweg 11	1	Vestas	850	Noordoostpolder	Flevoland	20-05-2004	
Espelerringweg 13	1	Vestas	850	Noordoostpolder	Flevoland	04-02-2005	
Espelerringweg 9	1	Vestas	660	Noordoostpolder	Flevoland	22-10-2002	
Essent	1	Lagerwey	80	Het Hogeland	Groningen	02-12-1995	01-07-2016
Essent	1	Lagerwey	750	Heerlen	Limburg	02-09-1999	
Estlandweg	1	Enercon	2300	Borsele	Zeeland	16-11-2015	
Estlandweg	1	Neg Micon	900	Borsele	Zeeland	02-07-2008	
Etten-Leur	5	Siemens	1300	Etten-Leur	Noord-Brabant	02-01-2000	
Europaweg-Zuid	4	Bouma	160	Borsele	Zeeland	02-01-1995	01-01-2014
Europaweg-Zuid	3	Bouma	160	Vlissingen	Zeeland	02-01-1995	01-07-2018

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Europaweg-Zuid Repower	3	Enercon	3000	Vlissingen	Zeeland	02-03-2014	
Europaweg-Zuid Repower	1	Enercon	3000	Borsele	Zeeland	02-03-2014	
EWI	7	Vestas	2000	Dronten	Flevoland	10-12-2002	
Fam. Bronsweg 87	1	Vestas	660	Delfzijl	Groningen	05-08-2000	
Ferwerderadiel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-01-1996	
Ferwerderadiel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-01-1992	
Ferwerderadiel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-11-1994	01-01-2013
Ferwerderadiel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-08-1992	
Ferwerderadiel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-01-1992	
Ferwerderadiel	1	Lagerwey	75	Noardeast-Fryslân	Fryslân	02-07-1989	
Ferwerderadiel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-11-1994	01-01-2013
Ferwerderadiel	1	Lagerwey	75	Noardeast-Fryslân	Fryslân	02-08-1990	
Ferwerderadiel	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-05-1994	
Ferwouderpad 2A	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	04-04-2003	
Flevoweg 1	1	Vestas	850	Hollands Kroon	Noord-Holland	06-04-2004	01-06-2015
Flevoweg 1	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Franekeradeel	1	Lagerwey	75	Waadhoeke	Fryslân	02-01-1991	
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-05-1994	
Franekeradeel	1	Lagerwey	75	Waadhoeke	Fryslân	02-11-1990	
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-06-1995	

VI.vi Overview of total installed and decommissioned Wind Turbines (cont.6) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-11-1990	
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-03-1992	
Franekeradeel	1	Lagerwey	75	Waadhoeke	Fryslân	02-09-1989	
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-01-1991	
Franekeradeel	1	Lagerwey	75	Waadhoeke	Fryslân	02-10-1989	
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-12-1995	
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-03-1991	
Franekeradeel	1	Lagerwey	80	Waadhoeke	Fryslân	02-05-1995	
Frankrijkweg	2	Neg Micon	900	Borsele	Zeeland	24-12-2004	
Franseweg	1	Lagerwey	75	Steenbergen	Noord-Brabant	02-04-1989	
Fri-Energy B.V.	1	Neg Micon	600	Waadhoeke	Fryslân	25-02-1998	
Friese Straatweg 17 Burum	1	Enercon	900	Noardeast-Fryslân	Fryslân	02-03-2016	
Frjentsjerterpaed 3	1	Neg Micon	750	Waadhoeke	Fryslân	16-05-2005	
Futenweg	6	Vestas	1750	Zeewolde	Flevoland	11-10-2002	
Gedeputeerde Laanweg 34	1	Vestas	850	Medemblik	Noord-Holland	27-03-2004	01-05-2017
Gedeputeerde Laanweg 34	1	Siemens Gamesa	850	Medemblik	Noord-Holland	02-06-2017	
Geestmerambacht	3	Micon	225	Langedijk	Noord-Holland	04-04-1996	01-04-2016
Gemini	75	Siemens	4000	Offshore	Offshore	02-07-2016	
Gemini	75	Siemens	4000	Offshore	Offshore	02-03-2016	
GEP Burum	1	Vestas	660	Noardeast-Fryslân	Fryslân	23-01-2001	01-01-2016

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Gerrit de Viesweg 16	1	Vestas	500	Medemblik	Noord-Holland	10-11-1995	01-01-2017
Gerrit de Viesweg 16	1	Enercon	900	Medemblik	Noord-Holland	01-12-2017	
Gerrit de Viesweg 17	1	Vestas	500	Medemblik	Noord-Holland	05-11-1995	01-01-2018
Gerrit de Viesweg 17	1	Enercon	900	Medemblik	Noord-Holland	01-03-2018	
Giessenwind	3	Enercon	3000	Molenlanden	Zuid-Holland	02-06-2013	
Goese Sas	1	Micon	250	Goes	Zeeland	09-02-1991	
Gooyumerweg 29	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	10-07-2002	
Greane Leane 2b	1	Micon	225	Tytsjerksteradiel	Fryslân	23-03-1995	
Greenchoice Hartelkanaal	8	Alstom	3000	Rotterdam	Zuid-Holland	16-12-2014	
Grevenweg	1	Bonus	300	De Fryske Marren	Fryslân	02-01-1995	
Griete	2	Enercon	800	Terneuzen	Zeeland	09-08-2007	
Grijpskerke	1	Bonus	300	Veere	Zeeland	02-01-1996	
Grindweg 1a	1	Neg Micon	900	Woensdrecht	Noord-Brabant	25-12-2001	
Groetpolder	19	Neg Micon	600	Hollands Kroon	Noord-Holland	27-07-1999	
Groettocht	7	Vestas	1650	Hollands Kroon	Noord-Holland	19-04-2003	01-12-2016
Grote Sloot	1	Enercon	2050	Schagen	Noord-Holland	16-11-2006	
GroWind	18	Vestas	3000	Het Hogeland	Groningen	02-07-2008	
GroWind	3	Vestas	3000	Het Hogeland	Groningen	02-07-2008	01-12-2016
GroWind	2	Lagerwey	4500	Het Hogeland	Groningen	02-05-2017	
Gruttoweg	2	Neg Micon	950	Zeewolde	Flevoland	13-12-2003	

VI.vii Overview of total installed and decommissioned Wind Turbines (cont.7) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Gruttoweg	2	Vestas	850	Zeewolde	Flevoland	15-10-2003	
Gruttoweg	2	Neg Micon	1000	Zeewolde	Flevoland	29-06-2005	
Gruttoweg	1	Vestas	850	Zeewolde	Flevoland	20-06-2003	
Gruttoweg	18	Vestas	850	Zeewolde	Flevoland	04-10-2002	
Gruttoweg	1	Vestas	660	Zeewolde	Flevoland	06-06-2000	
Grytmanswei	1	Bonus	300	Noardeast-Fryslân	Fryslân	02-01-1996	
Hagenwind	8	Enercon	2000	Aalten	Gelderland	05-07-2008	
Halsteren	8	Vestas	850	Bergen op Zoom	Noord-Brabant	18-12-2004	
Haringvliet	6	Bonus	600	Hellevoetsluis	Zuid-Holland	02-01-1997	
Harkstede	12	Lagerwey	80	Groningen	Groningen	02-04-1996	01-07-2016
Harstawei 12	1	Bonus	300	Súdwest-Fryslân	Fryslân	02-01-1996	
Hartelbrug II	8	Enercon	3000	Rotterdam	Zuid-Holland	02-05-2014	
Hartelbrug-West	6	Enercon	2000	Rotterdam	Zuid-Holland	15-01-2004	01-09-2017
Hartelkanaal	5	Nordex	2500	Rotterdam	Zuid-Holland	02-01-2004	
Hartelkanaal	4	Nordex	2500	Rotterdam	Zuid-Holland	02-01-2004	01-06-2016
Havenweg 03	1	Vestas	600	Noordoostpolder	Flevoland	16-11-1996	
Havenweg 20	1	Vestas	600	Noordoostpolder	Flevoland	17-11-1995	
Hayumerlaan 2	2	Micon	400	Súdwest-Fryslân	Fryslân	02-01-1996	
Hayumerleane 3	1	Vestas	850	Súdwest-Fryslân	Fryslân	14-02-2003	
Hazeldonk	3	Lagerwey	3000	Breda	Noord-Brabant	02-11-2015	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Headijk	1	Micon	225	Waadhoeke	Fryslân	29-04-1995	
Hearewei 12	1	Micon	225	Leeuwarden	Fryslân	22-06-1996	
Heerhugowaard	1	Lagerwey	75	Heerhugowaard	Noord-Holland	02-04-1989	
Hefswalsterweg 26	1	Vestas	850	Het Hogeland	Groningen	06-03-2004	
Hegenserleane 2a	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	09-06-2005	
Heidenskipsterdijk 06	1	EWT	900	Súdwest-Fryslân	Fryslân	01-08-2018	
Heidenskipsterdijk 06	1	Neg Micon	900	Súdwest-Fryslân	Fryslân	18-01-2003	01-04-2018
Heidenskipsterdijk 07	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	13-07-2001	01-01-2013
Heidenskipsterdijk 07	1	Vestas	850	Súdwest-Fryslân	Fryslân	02-10-2013	
Heidenskipsterdijk 44	1	Vestas	850	Súdwest-Fryslân	Fryslân	04-12-2003	
Heijbro	3	Enercon	2000	Lelystad	Flevoland	07-12-2005	
Hellegatsplein	4	Alstom	3000	Goeree-Overflakkee	Zuid-Holland	02-10-2015	
Hemert 13	1	Vestas	850	Súdwest-Fryslân	Fryslân	13-12-2003	
Hemmensewei 1B	1	Micon	225	Súdwest-Fryslân	Fryslân	08-10-1996	
Hemweg	8	Vestas	660	Amsterdam	Noord-Holland	27-03-2001	
Herbayum	4	Siemens Gamesa	850	Waadhoeke	Fryslân	02-06-2017	
Herbayum	10	NedWind	250	Waadhoeke	Fryslân	02-01-1995	01-06-2016
Herkingen	3	Neg Micon	2750	Goeree-Overflakkee	Zuid-Holland	09-03-2005	
Hesseweg Augsbuurt	1	Bonus	600	Noardeast-Fryslân	Fryslân	02-01-1996	
het Bildt	1	Lagerwey	80	Waadhoeke	Fryslân	02-10-1993	

VI.viii Overview of total installed and decommissioned Wind Turbines (cont.8) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
het Bildt	1	Lagerwey	75	Waadhoeke	Fryslân	02-04-1989	
het Bildt	1	Lagerwey	80	Waadhoeke	Fryslân	02-04-1994	
Het Nieuwland 2	1	Vestas	225	Den Helder	Noord-Holland	19-10-2002	
Hiddum-Houw	10	Vestas	500	Súdwest-Fryslân	Fryslân	08-01-1995	
Hikkaarderdyk 24	2	Bonus	250	Noardeast-Fryslân	Fryslân	02-01-1995	
Hitzum	1	Micon	225	Waadhoeke	Fryslân	02-01-1995	
Hoevensche Beemden	5	Vestas	3000	Halderberge	Noord-Brabant	02-01-2013	
Hogezandse Polder	9	Senvion	3400	Hoeksche Waard	Zuid-Holland	01-12-2018	
Hondtocht	6	Enercon	2300	Dronten	Flevoland	16-12-2012	
Hondtocht	8	Vestas	1750	Dronten	Flevoland	20-05-2004	01-01-2012
Hoofdplaatpolder	5	Vestas	2000	Sluis	Zeeland	06-04-2005	
Hoornseweg 14	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Hoornseweg 14	1	Vestas	850	Hollands Kroon	Noord-Holland	11-02-2004	01-06-2015
Hopweg 65	1	Vestas	660	Noordoostpolder	Flevoland	01-06-2005	
Houten	3	Vestas	2000	Houten	Utrecht	02-08-2013	
Houwdijk	1	Vestas	225	Súdwest-Fryslân	Fryslân	08-11-1998	
Ibisweg	5	Vestas	850	Zeewolde	Flevoland	30-07-2002	
Iendrachtswei 4	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	29-12-1999	
IFF	1	Nordex	2400	Tilburg	Noord-Brabant	02-06-2016	
Ijslandweg	1	Enercon	2300	Borsele	Zeeland	05-06-2012	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
IJzerpad 16	1	Vestas	600	Noordoostpolder	Flevoland	21-09-1996	
Indufor	9	Micon	250	Vlissingen	Zeeland	26-07-1989	01-12-2018
Indufor	4	Micon	250	Borsele	Zeeland	26-07-1989	01-12-2018
Irene Vorrink	9	Nordtank	600	Lelystad	Flevoland	29-04-1997	
Irene Vorrink	19	Nordtank	600	Dronten	Flevoland	31-08-1996	
Jaap Rodenburg	10	Vestas	1650	Almere	Flevoland	09-03-2000	
Jacoba Rippolder	5	Nordex	2500	Noord-Beveland	Zeeland	19-01-2008	
Jacobahaven	2	Vestas	3000	Noord-Beveland	Zeeland	04-10-2006	
Jacobahaven	1	Vestas	3000	Noord-Beveland	Zeeland	05-09-2006	
Jannumerwei	1	EWT	900	Noardeast-Fryslân	Fryslân	02-10-2013	
Joarumerlaene	2	Neg Micon	750	Súdwest-Fryslân	Fryslân	17-03-2005	
Johnson Europlant	1	Vestas	3000	De Ronde Venen	Utrecht	02-07-2009	
Jupiterweg 7	1	Neg Micon	1000	Leeuwarden	Fryslân	18-01-2006	
Jutrijp	1	Bonus	300	Súdwest-Fryslân	Fryslân	02-01-1996	
Kadal	2	Lagerwey	80	Waadhoeke	Fryslân	02-09-1993	
Kaderweg	1	Lagerwey	80	Schouwen-Duiveland	Zeeland	02-06-1992	
Kahoolsterlaan	1	Bonus	300	Noardeast-Fryslân	Fryslân	02-01-1997	
Kamperweg	1	Bonus	300	Súdwest-Fryslân	Fryslân	02-01-1996	
Kanaaldijk 1121	1	NedWind	250	Landsmeer	Noord-Holland	02-01-1995	
Kapelle-Schore	2	Vestas	225	Kapelle	Zeeland	27-08-1997	

VI.ix Overview of total installed and decommissioned Wind Turbines (cont.9) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Kats II	3	Vestas	3000	Noord-Beveland	Zeeland	06-06-2007	
Kattenberg-Reedijk	2	Nordex	2400	Oisterwijk	Noord-Brabant	16-08-2016	
Kattenberg-Reedijk	2	Nordex	2400	Oirschot	Noord-Brabant	16-08-2016	
Kennemerwind	6	Lagerwey	80	Schagen	Noord-Holland	02-10-1994	
Kennemerwind	3	Lagerwey	75	Schagen	Noord-Holland	02-03-1990	
Kerkmeerweg	3	Vestas	850	Langedijk	Noord-Holland	02-12-2011	
Kernweg	1	Vestas	225	Hoorn	Noord-Holland	12-05-1999	01-01-2013
Keteldiep 2	1	Neg Micon	750	Moerdijk	Noord-Brabant	16-11-1999	
Kilwind	4	Enercon	2300	Dordrecht	Zuid-Holland	16-11-2016	
Klapsterweg 92	1	Bonus	600	Delfzijl	Groningen	02-01-1998	
Kleasterdyk 2	1	Bonus	600	Súdwest-Fryslân	Fryslân	02-01-1997	
Klein Huisterweg 1	1	Vestas	850	Súdwest-Fryslân	Fryslân	27-09-2003	
Kleiweg	1	Bonus	600	Hollands Kroon	Noord-Holland	02-01-1998	
Klokbekertocht	6	Vestas	1650	Dronten	Flevoland	22-02-2002	
Klokbekerweg	1	Vestas	660	Lelystad	Flevoland	23-12-1998	
Klokbekerweg	1	Enercon	500	Lelystad	Flevoland	02-01-1997	
Klokbekerweg	2	Neg Micon	600	Lelystad	Flevoland	20-05-1998	
Kloosterboer	1	Enercon	2300	Borsele	Zeeland	02-03-2014	
Kloosterboer 2017	3	Enercon	2300	Vlissingen	Zeeland	02-07-2017	
Kloosterlanden	2	Enercon	2350	Deventer	Overijssel	16-09-2015	
Kloosterweg 09	1	Vestas	850	Súdwest-Fryslân	Fryslân	25-12-2002	
Klutenpad	2	Tacke	600	Noordoostpolder	Flevoland	02-01-1995	
Kluutmolen	10	Vestas	2000	Almere	Flevoland	02-07-2007	
Kluutweg	3	Vestas	850	Zeewolde	Flevoland	24-12-2003	
Knarweg	4	Neg Micon	900	Lelystad	Flevoland	30-12-2000	
Knarweg	10	Neg Micon	1000	Lelystad	Flevoland	11-11-2004	
Knarweg	1	Vestas	2000	Zeewolde	Flevoland	02-01-2009	
Knarweg	1	Neg Micon	900	Lelystad	Flevoland	26-01-2001	
Kneeshoek	8	Neg Micon	600	Hollands Kroon	Noord-Holland	25-02-1998	01-07-2018
Koegorspolder	22	Vestas	2000	Terneuzen	Zeeland	02-12-2007	
Kollumerland	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-01-1994	
Krabbedijk 2	1	Bonus	250	Súdwest-Fryslân	Fryslân	02-01-1995	
Krabbersgat	5	Enercon	800	Enkhuizen	Noord-Holland	12-12-2008	
Kralingseveer	1	Enercon	3000	Capelle aan den IJssel	Zuid-Holland	02-10-2016	
Krammer	5	Enercon	3000	Schouwen-Duiveland	Zeeland	02-10-2017	
Krammer	4	Enercon	3000	Schouwen-Duiveland	Zeeland	01-12-2018	
Krammer	6	Enercon	3000	Schouwen-Duiveland	Zeeland	11-01-2018	
Krammer	17	Enercon	3000	Schouwen-Duiveland	Zeeland	02-06-2018	
Krammer	2	Enercon	3000	Schouwen-Duiveland	Zeeland	02-08-2018	
Kreekraksluis	33	Nordex	2500	Reimerswaal	Zeeland	02-10-2013	

VI.x Overview of total installed and decommissioned Wind Turbines (cont.10) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Krimwei	1	Bonus	600	Súdwest-Fryslân	Fryslân	02-01-1998	
Kruisweg	1	Enercon	800	Hollands Kroon	Noord-Holland	02-08-2010	01-01-2013
Kubbeweg	17	Vestas	2000	Dronten	Flevoland	18-03-2006	
Kweldamweg	1	NoName	0	Molenlanden	Zuid-Holland	02-01-1985	
Laagwaalderweg	1	Bonus	300	Texel	Noord-Holland	02-01-1996	
Laaksche Vaart	5	Vestas	2000	Halderberge	Noord-Brabant	02-11-2014	
Laarakkerdijk	5	Senvion	2000	Reusel-De Mierden	Noord-Brabant	02-02-2015	
Lage Landen	1	Enercon	600	Rotterdam	Zuid-Holland	09-01-2001	
Landtong	2	Vestas	3000	Rotterdam	Zuid-Holland	02-10-2015	
Landtong Rozenburg	10	Neg Micon	1500	Rotterdam	Zuid-Holland	13-07-2007	
Lange Leane	1	Vestas	850	Súdwest-Fryslân	Fryslân	02-10-2013	
Lange Leane	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	18-12-2001	01-01-2011
Langelaan	2	Bonus	600	Den Helder	Noord-Holland	02-01-1998	
Langelaan	2	Lagerwey	80	Den Helder	Noord-Holland	02-07-1994	
Langelaan	1	Enercon	900	Den Helder	Noord-Holland	01-12-2018	
Lansinghage	3	Vestas	3000	Zoetermeer	Zuid-Holland	02-02-2011	
Leane 4	1	EWT	900	Waadhoeke	Fryslân	02-09-2017	
Leane 4	1	Nordtank	600	Waadhoeke	Fryslân	12-04-1997	01-03-2017
Leeuwarden	2	Enercon	900	Leeuwarden	Fryslân	02-06-2014	
Leeuwarden	1	Lagerwey	75	Leeuwarden	Fryslân	02-05-1989	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Leeuwarderadeel	1	Lagerwey	80	Leeuwarden	Fryslân	02-03-1992	
Leeuwarderadeel	1	Lagerwey	80	Leeuwarden	Fryslân	02-11-1993	
Leeuwarderadeel	1	Lagerwey	80	Leeuwarden	Fryslân	02-06-1995	
Leijepoel 5	1	Bonus	600	Súdwest-Fryslân	Fryslân	02-01-1998	
Lely Flevoland	2	Lagerwey	2600	Lelystad	Flevoland	02-03-2012	
Lely IJsselmeer	4	NedWind	500	Medemblik	Noord-Holland	02-01-1994	01-11-2016
Lelystad	1	Lagerwey	80	Lelystad	Flevoland	02-05-1995	
Lelystad	1	Lagerwey	80	Lelystad	Flevoland	02-05-1992	
Lelystad	1	Lagerwey	80	Lelystad	Flevoland	02-06-1996	
Lelystad-Noord	2	Enercon	3000	Lelystad	Flevoland	02-04-2015	
Lemsterland	1	Lagerwey	80	De Fryske Marren	Fryslân	02-12-1991	
Lepelaarpad	3	Neg Micon	950	Zeewolde	Flevoland	27-02-2003	
Lepelaarpad	1	Neg Micon	1000	Zeewolde	Flevoland	30-03-2005	
Lepelaarweg	1	Neg Micon	1000	Zeewolde	Flevoland	08-07-2004	
Lepelaarweg	5	Neg Micon	950	Zeewolde	Flevoland	04-04-2003	
Lepelaarweg	3	Neg Micon	1000	Zeewolde	Flevoland	10-03-2005	
Lepelaarweg	2	Vestas	850	Zeewolde	Flevoland	11-02-2004	
Lepelaarweg	1	Neg Micon	900	Zeewolde	Flevoland	16-03-2001	
Lepelaarweg	4	Neg Micon	950	Zeewolde	Flevoland	11-02-2003	
Leppedyk 57a	1	Bonus	300	Heerenveen	Fryslân	02-01-1996	01-05-2017

VI.xi Overview of total installed and decommissioned Wind Turbines (cont.11) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Leppedyk 57a	1	Siemens Gamesa	850	Heerenveen	Fryslân	02-06-2017	
Liefting	1	Enercon	2300	Alkmaar	Noord-Holland	02-06-2015	
Lijsbeth Tijs	6	Vestas	850	Koggenland	Noord-Holland	13-05-2004	01-02-2017
Lijsbeth Tijs	6	Siemens Gamesa	850	Koggenland	Noord-Holland	02-06-2017	
Lijsbeth Tijs	1	Vestas	850	Koggenland	Noord-Holland	13-05-2004	
Lisdoddeweg 33	1	Micon	225	Lelystad	Flevoland	02-11-1994	
Lisdoddeweg 42	1	Vestas	600	Lelystad	Flevoland	28-09-1996	
Lisdoddeweg 52	1	Vestas	660	Lelystad	Flevoland	25-10-1998	
Littensebuorren 6	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	16-02-2005	
Littenseradiel	1	Lagerwey	80	Leeuwarden	Fryslân	02-11-1994	
Littenseradiel	1	Lagerwey	80	Leeuwarden	Fryslân	02-07-1994	
Littenseradiel	1	Lagerwey	80	Súdwest-Fryslân	Fryslân	02-03-1996	
Littenseradiel	1	Lagerwey	80	Leeuwarden	Fryslân	02-12-1995	
Littenseradiel	1	Lagerwey	80	Súdwest-Fryslân	Fryslân	02-08-1993	
Littenseradiel	1	Lagerwey	80	Leeuwarden	Fryslân	02-10-1994	
Littenseradiel	1	Lagerwey	80	Súdwest-Fryslân	Fryslân	02-04-1996	
Littenseradiel	1	Lagerwey	80	Leeuwarden	Fryslân	02-01-1993	
Littenseradiel	1	Lagerwey	80	Súdwest-Fryslân	Fryslân	02-11-1994	
Littenseradiel	1	Lagerwey	80	Leeuwarden	Fryslân	02-01-1990	
Lopik	3	Vestas	2000	Lopik	Utrecht	02-07-2007	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Loppersum	1	NoName	0	Loppersum	Groningen	02-09-1982	
Lotwind	2	Bonus	300	Hollands Kroon	Noord-Holland	02-01-1996	
Luchterduinen	43	Vestas	3000	Offshore	Offshore	23-05-2015	
Maanderbroek	2	Siemens	3200	Ede	Gelderland	02-06-2015	
Maasmond	3	Vestas	3000	Rotterdam	Zuid-Holland	02-05-2013	
Madenlaan 2 Hindeloopen	1	EWT	900	Súdwest-Fryslân	Fryslân	02-06-2017	
Mammoettocht	10	Enercon	2300	Lelystad	Flevoland	25-08-2006	
Marconistraat	1	Enercon	2300	Harlingen	Fryslân	13-08-2005	
Marrum	7	Neg Micon	750	Noardeast-Fryslân	Fryslân	02-01-2008	
Martina Corneliapolder	4	Nordex	2500	Goeree-Overflakkee	Zuid-Holland	13-12-2011	
Medemblikkerweg 17	1	Vestas	850	Hollands Kroon	Noord-Holland	27-09-2003	01-06-2015
Medemblikkerweg 17	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Medemblikkerweg 29	1	Neg Micon	900	Hollands Kroon	Noord-Holland	05-07-2003	01-06-2015
Medemblikkerweg 29	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Meedhuizen	5	Nordex	600	Delfzijl	Groningen	02-01-1998	
Meeldijk	1	Lagerwey	80	Schouwen-Duiveland	Zeeland	02-09-1995	
Meerswal 02	1	Vestas	850	Súdwest-Fryslân	Fryslân	06-03-2004	
Meerswal 03	1	Vestas	850	Súdwest-Fryslân	Fryslân	18-06-2004	
Meerswal 09	1	Micon	225	Súdwest-Fryslân	Fryslân	19-09-1996	
Meerwind	1	Micon	250	Haarlemmermeer	Noord-Holland	23-12-1993	01-01-2013

VI.xii Overview of total installed and decommissioned Wind Turbines (cont.12) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Meerwind	1	Enercon	2300	Haarlemmermeer	Noord-Holland	02-06-2013	
Meerwind	1	Enercon	2050	Haarlemmermeer	Noord-Holland	02-06-2013	
Meeuwentocht	10	Enercon	1800	Lelystad	Flevoland	03-07-2003	
Menameradiel	1	Lagerwey	80	Waadhoeke	Fryslân	02-04-1996	
Menameradiel	1	Lagerwey	80	Waadhoeke	Fryslân	02-12-1999	
Menameradiel	1	Lagerwey	80	Waadhoeke	Fryslân	02-01-1995	
Menameradiel	1	Lagerwey	80	Waadhoeke	Fryslân	02-08-1994	
Menameradiel	1	Lagerwey	80	Waadhoeke	Fryslân	02-04-1996	
Middenweg	1	Bonus	300	Schagen	Noord-Holland	02-01-1996	
Middenweg	1	Bonus	300	Hollands Kroon	Noord-Holland	02-01-1996	
Middenweg 49-1	1	Vestas	1750	Moerdijk	Noord-Brabant	08-10-2002	
Middenweg 49-2	1	Vestas	1750	Moerdijk	Noord-Brabant	15-02-2002	
Midlum	6	Vestas	850	Harlingen	Fryslân	31-10-2008	01-06-2016
Midlum	6	Enercon	2300	Harlingen	Fryslân	02-11-2016	
Mieddyk 09	1	Vestas	850	Noardeast-Fryslân	Fryslân	02-01-1999	
Miedweg 10	1	Micon	600	Noardeast-Fryslân	Fryslân	08-02-1995	
Molenweg 1	1	Vestas	850	Hollands Kroon	Noord-Holland	18-09-2003	
Monnikeweg 2	1	Vestas	850	Súdwest-Fryslân	Fryslân	05-03-2003	
Mousamabuorren 02	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	24-08-2002	
Nagelerweg 23	1	Neg Micon	750	Noordoostpolder	Flevoland	31-03-1999	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Nauerna	2	Enercon	2050	Zaanstad	Noord-Holland	13-12-2007	
Neefje	1	Lagerwey	250	Rotterdam	Zuid-Holland	02-04-1996	01-01-2012
Neeltje Jans	4	Vestas	3000	Veere	Zeeland	05-09-2006	
Neer	4	Enercon	2300	Leudal	Limburg	31-05-2012	
Neer	1	Enercon	2350	Leudal	Limburg	02-10-2015	
Nerefco	9	Nordex	2500	Rotterdam	Zuid-Holland	02-01-2002	
Nesserlaan 2	1	Vestas	850	Súdwest-Fryslân	Fryslân	12-12-2003	
Netterden Azewijn	4	Lagerwey	2300	Oude IJsselstreek	Gelderland	02-09-2016	
Netterden Azewijn	2	Lagerwey	2300	Montferland	Gelderland	02-09-2016	
Neushoorntocht	10	Enercon	2300	Lelystad	Flevoland	13-10-2006	
Niedorp	1	Lagerwey	80	Hollands Kroon	Noord-Holland	02-05-1996	
Nieuw Almersdorperweg 01	1	Vestas	850	Hollands Kroon	Noord-Holland	02-07-2010	
Nieuw Almersdorperweg 05	1	Vestas	850	Hollands Kroon	Noord-Holland	03-09-2003	
Nieuw Almersdorperweg 11	1	Vestas	850	Hollands Kroon	Noord-Holland	28-11-2009	
Nieuw-Prinsenland	4	Siemens	3200	Steenbergen	Noord-Brabant	02-04-2015	
Nieuwe Waterweg	6	Vestas	3450	Rotterdam	Zuid-Holland	01-04-2019	
Nieuwegein	5	Vestas	2000	Nieuwegein	Utrecht	26-12-2014	
Nieuwesluizerweg 13	1	Vestas	850	Hollands Kroon	Noord-Holland	02-04-2004	
Nieuweweg 5	1	Neg Micon	950	Noardeast-Fryslân	Fryslân	09-12-2003	
Nieuweweg Marrum	1	Vestas	850	Noardeast-Fryslân	Fryslân	02-12-2011	

VI.xiii Overview of total installed and decommissioned Wind Turbines (cont.13) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Nijmegen-Betuwe	4	Lagerwey	2520	Nijmegen	Gelderland	16-11-2016	
Noordenwind	1	Lagerwey	75	Noardeast-Fryslân	Fryslân	02-06-1989	
Noordenwind	1	Lagerwey	75	Groningen	Groningen	02-05-1990	
Noordenwind	1	Lagerwey	75	Noardeast-Fryslân	Fryslân	02-07-1988	
Noordenwind	1	Lagerwey	80	Noardeast-Fryslân	Fryslân	02-04-1993	
Noordenwind	1	Lagerwey	75	Waadhoeke	Fryslân	02-07-1988	
Noorderdijkerweg 18	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Noorderdijkerweg 18	1	Neg Micon	900	Hollands Kroon	Noord-Holland	23-06-2004	01-06-2015
Noorderkwelweg 16	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Noorderlaan 20	1	Vestas	850	Súdwest-Fryslân	Fryslân	29-10-2003	
Noordermeerweg	1	Tacke	600	Noordoostpolder	Flevoland	02-01-1995	
Noordermeerweg 5	1	Vestas	600	Noordoostpolder	Flevoland	23-05-1997	
Noorderpolder	5	EWT	900	Waadhoeke	Fryslân	02-06-2017	
Noorderpolder	5	Nordtank	600	Waadhoeke	Fryslân	24-12-1997	01-03-2017
Noordertocht	6	Vestas	1750	Lelystad	Flevoland	09-11-2002	
Noorderwind	4	Vestas	2000	Dronten	Flevoland	15-03-2003	
Noordoostpolder	1	Lagerwey	80	Noordoostpolder	Flevoland	02-12-1995	
Noordoostpolder	1	Lagerwey	80	Noordoostpolder	Flevoland	02-09-1995	
Noordoostpolder	1	Lagerwey	75	Noordoostpolder	Flevoland	02-08-1989	
Noordoostpolder	1	Lagerwey	250	Noordoostpolder	Flevoland	02-12-1995	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Noordoostpolder	1	Lagerwey	80	Noordoostpolder	Flevoland	02-11-1995	
Noordoostpolder	1	Lagerwey	80	Noordoostpolder	Flevoland	02-10-1989	
Noordoostpolder	1	Lagerwey	80	Noordoostpolder	Flevoland	02-08-1995	
Noordoostpolder	1	Lagerwey	750	Noordoostpolder	Flevoland	02-04-2002	
Noordoostpolder Buitendijks	42	Siemens	3000	Noordoostpolder	Flevoland	02-12-2015	
Noordoostpolder Buitendijks	6	Siemens	3000	De Fryske Marren	Fryslân	02-12-2015	
Noordpolder	4	Enercon	2300	Tholen	Zeeland	08-04-2011	
Noordpolderweg	1	Vestas	660	Het Hogeland	Groningen	01-06-2001	01-01-2011
Noordpolderweg 03	1	Vestas	850	Het Hogeland	Groningen	02-07-2010	
Noordpolderweg 06	1	Vestas	660	Het Hogeland	Groningen	01-06-2001	01-10-2016
Noordpolderweg 3 Westernieland	1	Vestas	850	Het Hogeland	Groningen	02-12-2011	
Noordpolderweg 6 Westernieland	1	Vestas	850	Het Hogeland	Groningen	02-11-2016	
Noordzeeweg	7	Vestas	660	Amsterdam	Noord-Holland	21-02-2001	
NOP	4	Enercon	7500	Noordoostpolder	Flevoland	01-12-2016	
NOP	3	Enercon	7500	Noordoostpolder	Flevoland	04-11-2015	
NOP	5	Enercon	7500	Noordoostpolder	Flevoland	02-01-2017	
NOP	15	Enercon	7500	Noordoostpolder	Flevoland	02-05-2015	
NOP	6	Enercon	7500	Noordoostpolder	Flevoland	02-12-2014	
NOP	1	Enercon	7500	Noordoostpolder	Flevoland	20-08-2014	
NOP	4	Enercon	7500	Noordoostpolder	Flevoland	02-08-2015	

VI.xiv Overview of total installed and decommissioned Wind Turbines (cont.14) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Norderkwelweg 16	1	Vestas	850	Hollands Kroon	Noord-Holland	26-09-2003	01-06-2015
Nummer (N354)	1	Bonus	300	Súdwest-Fryslân	Fryslân	02-01-1996	
Nummer 04	1	Neg Micon	950	Súdwest-Fryslân	Fryslân	06-12-2003	
NUON	1	Lagerwey	75	Waadhoeke	Fryslân	02-08-1991	
NUON	1	Lagerwey	80	De Fryske Marren	Fryslân	02-09-1993	
NUON	1	Lagerwey	80	Harlingen	Fryslân	02-06-1991	
NUON	1	Lagerwey	75	Harlingen	Fryslân	02-04-1990	
O. Nieuwkruisland 08	1	Vestas	850	Noardeast-Fryslân	Fryslân	10-03-2004	
Ohmstraat 1	1	Neg Micon	900	Waadhoeke	Fryslân	21-01-2005	
Olaz	3	Vestas	660	Borsele	Zeeland	07-03-2001	
Olaz	3	Enercon	2300	Borsele	Zeeland	02-09-2017	
Olaz	2	Vestas	660	Borsele	Zeeland	25-03-2000	01-06-2017
Oldebroekertocht	6	Enercon	2300	Dronten	Flevoland	04-08-2011	
Olster-Tocht	6	Vestas	2000	Dronten	Flevoland	23-06-2002	
Ommelanderweg	1	Bonus	600	Het Hogeland	Groningen	02-01-1996	01-07-2016
Ommelanderweg 12	1	Vestas	850	Het Hogeland	Groningen	02-07-2008	
Ommelanderweg 18	1	Vestas	850	Het Hogeland	Groningen	02-07-2008	
Ommelanderweg 28 Hornhuizen	1	EWT	900	Het Hogeland	Groningen	02-08-2016	
Ooievaarsweg	14	Neg Micon	950	Zeewolde	Flevoland	18-12-2003	
Ooievaarsweg	1	Neg Micon	900	Zeewolde	Flevoland	12-06-2004	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Oom Kees	2	Vestas	3000	Hollands Kroon	Noord-Holland	02-01-2010	
Oostelijke Industrieweg	1	Micon	225	Waadhoeke	Fryslân	02-01-1995	
Oostelijke Industrieweg 22	1	Neg Micon	900	Súdwest-Fryslân	Fryslân	02-10-2002	01-05-2016
Oostelijke Industrieweg 22 Franeker	1	Vestas	850	Waadhoeke	Fryslân	02-06-2016	
Oostelijke Industrieweg 23	1	Neg Micon	900	Waadhoeke	Fryslân	02-07-2009	
Oostelijke Industrieweg 6	1	NoName	0	Waadhoeke	Fryslân	02-01-1999	
Oosterkwelweg 16	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Oosterkwelweg 16	1	Vestas	850	Hollands Kroon	Noord-Holland	25-09-2003	01-06-2015
Oosterkwelweg 19	1	Vestas	850	Hollands Kroon	Noord-Holland	25-02-2004	
Oosterlaan 6 Schraard	1	EWT	900	Súdwest-Fryslân	Fryslân	02-06-2016	
Oosterterpweg 12	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Oosterterpweg 12	1	Neg Micon	900	Hollands Kroon	Noord-Holland	23-06-2004	01-06-2015
Oosterterpweg 16	1	Vestas	850	Hollands Kroon	Noord-Holland	18-02-2004	
Oosterterpweg 24	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Oosterterpweg 24	1	Neg Micon	900	Hollands Kroon	Noord-Holland	13-02-2004	01-06-2015
Oosterterpweg 38	1	Neg Micon	900	Hollands Kroon	Noord-Holland	20-03-2004	01-06-2015
Oosterterpweg 38	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Oostoeverweg	1	Vestas	660	Den Helder	Noord-Holland	29-12-2006	
Oostpolderweg 07	1	Vestas	660	Delfzijl	Groningen	19-06-2001	
Oostpolderweg 21	1	Vestas	660	Delfzijl	Groningen	21-06-2001	

VI.xv Overview of total installed and decommissioned Wind Turbines (cont.15) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Ooststellingwerf	1	Lagerwey	75	Ooststellingwerf	Fryslân	02-12-1988	
Oostwind	2	Enercon	600	Koggenland	Noord-Holland	04-02-2004	
Ossenkampweg 02	1	Neg Micon	900	Zeewolde	Flevoland	24-08-2002	
Ossenkampweg 05	1	Nordtank	500	Zeewolde	Flevoland	15-12-1996	
Ossenkampweg 09	1	Vestas	850	Zeewolde	Flevoland	06-09-2002	
Ossenkampweg 12	1	Neg Micon	950	Zeewolde	Flevoland	18-04-2003	
Ossenkampweg 13	1	Neg Micon	900	Zeewolde	Flevoland	24-08-2002	
Ossenkampweg 16	1	Neg Micon	900	Zeewolde	Flevoland	24-08-2002	
Ossenkampweg 17	1	Vestas	850	Zeewolde	Flevoland	14-08-2002	
Ottemalaan 1	1	Vestas	600	Waadhoeke	Fryslân	12-09-1996	
Oud Dintel	5	Siemens	3200	Moerdijk	Noord-Brabant	16-01-2016	
Oude Bildtzijl	1	Micon	225	Waadhoeke	Fryslân	02-01-1995	
Oude Prov. Weg 4 Nieuwe Niedorp	1	EWT	900	Hollands Kroon	Noord-Holland	02-01-2016	
Oudega	1	EWT	900	De Fryske Marren	Fryslân	02-04-2010	
Oudelandertocht	12	Vestas	1650	Hollands Kroon	Noord-Holland	16-08-2002	01-05-2017
Oudelanderweg	3	Vestas	850	Hollands Kroon	Noord-Holland	05-09-2003	01-06-2015
Oudelanderweg	3	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Oudemirdum	1	EWT	900	De Fryske Marren	Fryslân	02-04-2010	
Oudendijk	6	Enercon	800	Koggenland	Noord-Holland	22-12-2007	
Oudenstaart	2	Vestas	2000	Tilburg	Noord-Brabant	02-09-2011	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Oudenstaart	3	Vestas	2000	Tilburg	Noord-Brabant	02-09-2011	
Papemeer	2	Enercon	2050	Zoeterwoude	Zuid-Holland	26-10-2005	01-12-2015
Parallelweg	1	Enercon	800	Schagen	Noord-Holland	27-10-2009	
Perdok Usquert	1	EWT	900	Het Hogeland	Groningen	02-03-2015	
Peutweg	1	Lagerwey	80	Barneveld	Gelderland	02-01-1996	
Piet de Wit	12	Vestas	1750	Goeree-Overflakkee	Zuid-Holland	12-04-2003	
Pijlstaartweg	6	Enercon	2000	Lelystad	Flevoland	17-02-2004	
Pijlstaartweg	1	Lagerwey	80	Lelystad	Flevoland	02-01-1996	
Pijlstaartweg	6	Neg Micon	1000	Lelystad	Flevoland	29-12-2005	
Plavuizenweg 01	1	Neg Micon	600	Lelystad	Flevoland	15-10-1999	
Plavuizenweg 6	2	Neg Micon	1750	Lelystad	Flevoland	02-10-2004	
Plavuizenweg 6	1	Neg Micon	750	Lelystad	Flevoland	09-09-1999	
Poelweg 12	1	Micon	600	Medemblik	Noord-Holland	06-10-1995	
Polenweg	1	Tacke	600	Noordoostpolder	Flevoland	02-01-1995	
Priempad	1	Lagerwey	80	Zeewolde	Flevoland	02-03-1990	
Prinses Alexia	36	Senvion	3400	Zeewolde	Flevoland	02-09-2013	
Prinses Amalia	60	Vestas	2000	Offshore	Offshore	02-06-2008	
Procter & Gamble	1	Senvion	2050	Coevorden	Drenthe	02-08-2010	
Prof. Brandsmaweg 12	1	Vestas	225	Noordoostpolder	Flevoland	29-11-1997	
Provincialeweg	1	Bonus	300	Hollands Kroon	Noord-Holland	02-01-1996	

VI.xvi Overview of total installed and decommissioned Wind Turbines (cont.16) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Provincialeweg	1	Enercon	2050	Hollands Kroon	Noord-Holland	13-07-2010	
Putten	1	Lagerwey	50	Putten	Gelderland	02-01-1994	
Rachel Carson (Eemmeerdijk)	1	NedWind	1000	Zeewolde	Flevoland	02-01-1998	02-02-2006
Rachel Carson (Eemmeerdijk)	17	NedWind	1000	Zeewolde	Flevoland	02-01-1998	
Reigerweg	2	Lagerwey	80	Zeewolde	Flevoland	02-02-1994	
Reigerweg	3	Vestas	850	Zeewolde	Flevoland	21-05-2003	
Reigerweg	1	Neg Micon	950	Zeewolde	Flevoland	30-01-2003	
Reigerweg	2	Neg Micon	950	Zeewolde	Flevoland	30-10-2003	
Reigerweg	2	Neg Micon	900	Zeewolde	Flevoland	19-02-2003	
Reigerweg	1	Vestas	660	Zeewolde	Flevoland	30-10-1999	
Reigerweg	1	Neg Micon	950	Zeewolde	Flevoland	25-04-2003	
Reigerweg	4	Neg Micon	900	Zeewolde	Flevoland	16-03-2001	
Rembrandt	1	Enercon	2300	Vlissingen	Zeeland	06-06-2015	
Rembrandt	3	Vestas	2000	Coevorden	Drenthe	02-11-2014	
Rembrandt	1	Enercon	2300	Westland	Zuid-Holland	16-12-2015	
Rendierweg 47	1	Vestas	600	Dronten	Flevoland	08-06-1996	
Riedsterwei 3	1	Micon	225	Waadhoeke	Fryslân	29-07-1994	
Riegeweg 7	1	Vestas	850	Súdwest-Fryslân	Fryslân	24-02-2004	
Rijksstraatweg 68	1	Siemens Gamesa	850	Heerenveen	Fryslân	02-06-2017	
Rijksstraatweg 68	1	Nordtank	600	Heerenveen	Fryslân	10-11-1998	01-05-2017

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Rijnwoude	4	Vestas	3000	Alphen aan den Rijn	Zuid-Holland	29-06-2007	
Ritthem	1	NedWind	500	Vlissingen	Zeeland	02-01-1997	01-01-2013
Rivierduintocht	7	Vestas	1650	Dronten	Flevoland	28-12-2006	
Rivierduinweg 04	1	Vestas	225	Dronten	Flevoland	21-11-1995	
Robbenoordweg 14	1	Vestas	850	Hollands Kroon	Noord-Holland	11-10-2003	01-06-2015
Robbenoordweg 14	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Roggeplaat	4	Enercon	2300	Schouwen-Duiveland	Zeeland	02-12-2012	
Ronde Venen	1	Lagerwey	80	De Ronde Venen	Utrecht	02-01-1994	
Roodehaansterweg	1	EWT	900	Het Hogeland	Groningen	02-03-2014	
Roompotsluis	4	Vestas	3000	Veere	Zeeland	05-09-2006	
Roosendaalsche Vliet	3	Vestas	3000	Roosendaal	Noord-Brabant	02-12-2015	
Runderweg	2	Neg Micon	1000	Lelystad	Flevoland	02-02-2005	
Runderweg	1	Neg Micon	600	Lelystad	Flevoland	11-07-1998	
Sabina polder	3	Vestas	3000	Moerdijk	Noord-Brabant	21-12-2014	
Sabinapolder	7	Vestas	850	Moerdijk	Noord-Brabant	02-07-2009	
Sagro Vlissingen-Oost	3	Enercon	2300	Borsele	Zeeland	01-03-2018	
Samen voor de Wind	7	Enercon	1800	Dronten	Flevoland	03-01-2003	
Sarabos 13	1	Vestas	660	Achtkarspelen	Fryslân	20-06-2000	
Sasputsestraat	1	Lagerwey	80	Sluis	Zeeland	02-11-1991	
Schagen	1	Lagerwey	80	Schagen	Noord-Holland	02-08-2003	

VI.xvii Overview of total installed and decommissioned Wind Turbines (cont.17) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Schagen	8	Enercon	800	Schagen	Noord-Holland	15-10-2008	
Schagen	1	Lagerwey	80	Schagen	Noord-Holland	02-03-1996	
Schagen	1	Lagerwey	80	Schagen	Noord-Holland	02-06-1996	
Scharnegoutum	1	Vestas	660	Súdwest-Fryslân	Fryslân	24-04-1999	
Scharnerbuursterweg 29	1	Vestas	850	Súdwest-Fryslân	Fryslân	20-04-2004	
Scheemda	12	Lagerwey	80	Oldambt	Groningen	02-11-1993	01-06-2016
Schelpenbolweg 2	1	Vestas	850	Hollands Kroon	Noord-Holland	17-03-2004	01-06-2015
Schelpenbolweg 2	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Schelpenbolweg 26	1	Neg Micon	900	Hollands Kroon	Noord-Holland	20-03-2004	
Schelpenbolweg 42	1	Neg Micon	900	Hollands Kroon	Noord-Holland	20-03-2004	01-06-2015
Schelpenbolweg 42	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Schervenweg 12	1	Enercon	800	Hollands Kroon	Noord-Holland	01-09-2017	
Schervenweg 12	1	Vestas	850	Hollands Kroon	Noord-Holland	29-08-2007	01-07-2017
Schervenweg 23	1	Neg Micon	900	Hollands Kroon	Noord-Holland	10-03-2005	
Schervenweg 34	1	Neg Micon	900	Hollands Kroon	Noord-Holland	13-02-2004	
Schillinkweg	2	Lagerwey	80	Zeewolde	Flevoland	02-09-1995	01-01-2013
Schollevaarweg	2	Neg Micon	1000	Zeewolde	Flevoland	18-09-2004	
Schollevaarweg	1	Vestas	850	Zeewolde	Flevoland	05-07-2003	
Schollevaarweg	1	Neg Micon	600	Zeewolde	Flevoland	26-10-1999	
Schollevaarweg	1	Neg Micon	900	Zeewolde	Flevoland	03-05-2006	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Schollevaarweg	1	Neg Micon	950	Zeewolde	Flevoland	12-11-2004	
Schollevaarweg	1	Neg Micon	950	Zeewolde	Flevoland	20-12-2003	
Schollevaarweg	1	Vestas	850	Zeewolde	Flevoland	17-12-2002	
Schollevaarweg	2	Neg Micon	1000	Zeewolde	Flevoland	18-02-2005	
Schollevaarweg	1	Vestas	850	Zeewolde	Flevoland	02-07-2004	
Schollevaarweg	4	Neg Micon	950	Zeewolde	Flevoland	15-01-2003	
Schollevaarweg	1	Neg Micon	750	Zeewolde	Flevoland	16-09-1999	
Schollevaarweg	1	Vestas	850	Zeewolde	Flevoland	10-05-2005	
Schorweg	1	Lagerwey	250	Hollands Kroon	Noord-Holland	01-01-1996	
Schuttingsteeg	1	Nordtank	300	Noardeast-Fryslân	Fryslân	02-01-1996	
Seepmawei	1	Bonus	300	Noardeast-Fryslân	Fryslân	02-01-1995	
Sieswerd 13	1	Vestas	850	Súdwest-Fryslân	Fryslân	28-12-2002	
Sjaerdaleane 19	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	16-02-2005	
Skarsterlan	1	NoName	0	De Fryske Marren	Fryslân	02-11-1990	
Skarsterlan	1	Lagerwey	80	De Fryske Marren	Fryslân	02-03-1992	
Skarsterlan	1	Lagerwey	80	De Fryske Marren	Fryslân	02-08-1993	
Skippersbuorren 19	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	17-03-2005	
Skrins 4	1	Neg Micon	750	Leeuwarden	Fryslân	16-02-2005	
Slachtedijk 4	1	Micon	225	Waadhoeke	Fryslân	27-04-1995	01-01-2014
Slingerweg	1	Lagerwey	80	Zeewolde	Flevoland	02-01-1993	01-01-2013

VI.xviii Overview of total installed and decommissioned Wind Turbines (cont.18) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Slinkewei 15	1	Vestas	850	Súdwest-Fryslân	Fryslân	21-02-2003	
Slinkewei 15a	1	Vestas	850	Súdwest-Fryslân	Fryslân	21-04-2004	
Sloewind	1	Neg Micon	750	Borsele	Zeeland	09-12-1999	
Sloewind	7	Neg Micon	750	Vlissingen	Zeeland	09-12-1999	
Slootweg 6	1	Neg Micon	900	Hollands Kroon	Noord-Holland	20-03-2004	01-06-2015
Slootweg 6	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Sloterdijk	4	Vestas	660	Amsterdam	Noord-Holland	07-02-2001	
Sloteroog	4	NedWind	250	Haarlem	Noord-Holland	02-01-1995	01-06-2018
Slufter 2	14	Vestas	3600	Rotterdam	Zuid-Holland	01-02-2019	
Slufterdijk Noord	8	GE Wind	1500	Rotterdam	Zuid-Holland	02-01-2004	01-01-2018
Slufterdijk West	9	GE Wind	1500	Rotterdam	Zuid-Holland	02-01-2004	01-08-2017
Sondel	1	EWT	900	De Fryske Marren	Fryslân	02-04-2010	
Sortiva	2	Enercon	2300	Alkmaar	Noord-Holland	03-05-2012	
Spijkster Oudedijk 4	1	Vestas	600	Delfzijl	Groningen	05-06-1998	01-06-2016
Spijkster Oudedijk 4	1	EWT	900	Delfzijl	Groningen	02-08-2016	
Spoorwind	3	Enercon	2000	Staphorst	Overijssel	04-12-2003	01-02-2018
Spui	5	Enercon	4200	Hoeksche Waard	Zuid-Holland	01-12-2018	
St. Antoinedijk	5	Vestas	2000	Halderberge	Noord-Brabant	02-07-2009	
Stadhoudersweg 73	1	Bonus	600	Waadhoeke	Fryslân	02-01-1998	
Stationswei 30	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	20-04-2001	01-01-2013

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Stationswei Molkwerum	1	Vestas	850	Súdwest-Fryslân	Fryslân	02-10-2013	
Stavenisse	3	Vestas	225	Tholen	Zeeland	27-06-1995	01-04-2016
Sterappellaan	1	Neg Micon	1000	Zeewolde	Flevoland	13-04-2005	
Sterappellaan	5	Neg Micon	950	Zeewolde	Flevoland	08-07-2004	
Sterappellaan	1	Vestas	850	Zeewolde	Flevoland	05-08-2004	
Sterappellaan	2	Vestas	850	Zeewolde	Flevoland	05-05-2005	
Sterappellaan	1	Neg Micon	900	Zeewolde	Flevoland	12-04-2006	
Sternweg	9	Enercon	3000	Zeewolde	Flevoland	25-07-2013	
Stichting Wiek	1	Bonus	300	Súdwest-Fryslân	Fryslân	02-01-1996	
Stienzer Hegedyk	1	Bonus	300	Leeuwarden	Fryslân	02-01-1995	
Suderdijk 03	1	Vestas	660	Súdwest-Fryslân	Fryslân	20-12-2000	
Sudhoeke 1 Wommels	1	Neg Micon	750	Súdwest-Fryslân	Fryslân	02-07-2004	
Sudhoeke 3 Wommels	1	Vestas	850	Súdwest-Fryslân	Fryslân	02-01-2014	
Sudhoeke 3 Wommels	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	24-05-2001	01-03-2014
Suurhoffbrug	4	Enercon	3000	Rotterdam	Zuid-Holland	02-07-2013	
Swifteringweg 11	1	Nordtank	600	Lelystad	Flevoland	29-11-1997	
Swifteringweg 15	1	Neg Micon	750	Lelystad	Flevoland	07-12-2000	
Swingmalaan	1	Enercon	900	Harlingen	Fryslân	02-09-2014	
Swingmalaan	1	Vestas	500	Harlingen	Fryslân	17-05-1995	01-03-2014
Synergieweg	1	Vestas	3450	Het Hogeland	Groningen	16-10-2015	

VI.xix Overview of total installed and decommissioned Wind Turbines (cont.19) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
t Nauwster Hoek VOF	1	Neg Micon	900	Súdwest-Fryslân	Fryslân	10-07-2004	
Ter Laan 19	1	Vestas	600	Het Hogeland	Groningen	07-05-1996	01-01-2015
Terdiek	1	Bonus	300	Hollands Kroon	Noord-Holland	02-01-1996	01-01-2013
Terdiek	1	Enercon	2050	Hollands Kroon	Noord-Holland	02-12-2012	
Terdiek 16	1	Bonus	600	Hollands Kroon	Noord-Holland	01-08-2002	
Test Site Lelystad	1	Siemens	2300	Lelystad	Flevoland	05-10-2012	
Test Site Lelystad	1	Enercon	4200	Lelystad	Flevoland	02-05-2016	
Test Site Lelystad	1	Leitwind	3000	Lelystad	Flevoland	02-11-2013	
Test Site Lelystad	1	Enercon	3200	Lelystad	Flevoland	01-06-2018	
Test Site Lelystad	1	EWT	900	Lelystad	Flevoland	01-09-2015	
Test Site Lelystad	1	Enercon	3000	Lelystad	Flevoland	02-06-2015	
Theemsweg	1	Vestas	660	Amsterdam	Noord-Holland	02-01-2002	
Tichelwurk	1	Nordtank	600	Waadhoeke	Fryslân	16-10-1999	01-06-2015
Tichelwurk	1	EWT	900	Waadhoeke	Fryslân	02-11-2015	
Tjessinga	1	Nordex	3600	Het Hogeland	Groningen	01-09-2018	
Tjessinga	11	Nordtank	500	Waadhoeke	Fryslân	15-10-1995	
Tolhuislanden	1	Enercon	3000	Zwolle	Overijssel	28-04-2012	
Tolhuislanden	3	Enercon	2300	Zwolle	Overijssel	28-04-2012	
Tollebekerweg	1	Bonus	300	Noordoostpolder	Flevoland	02-01-1996	
Trekwei 12	1	Neg Micon	950	Súdwest-Fryslân	Fryslân	19-12-2003	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Treurenburg	1	Enercon	2300	s-Hertogenbosch	Noord-Brabant	03-03-2011	
Tureluurweg	2	Vestas	850	Zeewolde	Flevoland	11-10-2002	
Tweehuizerweg 01	1	Vestas	850	Het Hogeland	Groningen	09-02-2002	
Twilling	2	Nordtank	500	De Fryske Marren	Fryslân	02-01-1997	
Tzum	1	Micon	225	Waadhoeke	Fryslân	02-01-1995	01-07-2016
Uitdammerdijk	1	Bouma	160	Amsterdam	Noord-Holland	02-01-1993	
Ulketocht	8	Lagerwey	750	Hollands Kroon	Noord-Holland	02-03-2003	01-11-2016
Uranusweg 01	1	Neg Micon	1000	Leeuwarden	Fryslân	22-04-2006	
Ursuladijk 22	1	Neg Micon	950	Súdwest-Fryslân	Fryslân	06-12-2003	
Van Ewijcksvaart 08	1	Vestas	225	Hollands Kroon	Noord-Holland	04-05-1996	
Van Gogh	5	Enercon	2300	Etten-Leur	Noord-Brabant	02-01-2013	
Van Luna	3	Enercon	2300	Heerhugowaard	Noord-Holland	30-07-2010	
Van Pallandt	7	Vestas	2000	Goeree-Overflakkee	Zuid-Holland	06-05-2006	
Veerweg	1	Enercon	800	Hollands Kroon	Noord-Holland	17-11-2010	
Veerweg	1	Bonus	300	Hollands Kroon	Noord-Holland	02-01-1996	
Velsen	3	Vestas	3000	Velsen	Noord-Holland	02-10-2011	
Veluwe Windt	2	Lagerwey	80	Schouwen-Duiveland	Zeeland	02-03-1993	
Visafslag	1	Lagerwey	75	Het Hogeland	Groningen	02-01-1988	
Visvijverweg	3	Enercon	500	Lelystad	Flevoland	02-01-1997	
Visvijverweg	1	Neg Micon	600	Lelystad	Flevoland	20-05-1998	

VI.xx Overview of total installed and decommissioned Wind Turbines (cont.20) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Visvijverweg	1	Vestas	850	Lelystad	Flevoland	12-01-2001	
Visvijverweg	1	Neg Micon	600	Lelystad	Flevoland	24-12-1998	
Visvijverweg	1	Neg Micon	750	Lelystad	Flevoland	24-12-1998	
Vlaardingen	2	Vestas	3000	Vlaardingen	Zuid-Holland	02-08-2014	
Vliegtuigweg 02	1	Vestas	660	Noordoostpolder	Flevoland	17-12-1998	
Vlissingen buitenhaven	7	Vestas	225	Vlissingen	Zeeland	26-08-1997	
Volkerak	11	Vestas	850	Moerdijk	Noord-Brabant	04-06-2005	
Voltastraat 09	1	Neg Micon	900	Waadhoeke	Fryslân	21-09-2006	
Vuursteentocht	4	Vestas	2000	Lelystad	Flevoland	12-12-2003	
W. Binnemaleane	3	Lagerwey	80	Waadhoeke	Fryslân	02-01-1994	
W3 Energie	1	Enercon	800	Hollands Kroon	Noord-Holland	27-11-2010	
W3 Energie	1	Enercon	800	Hollands Kroon	Noord-Holland	29-06-2012	
Waardpolder	19	NedWind	250	Hollands Kroon	Noord-Holland	02-01-1997	01-11-2017
Waardpolderhoofdweg	1	Micon	600	Hollands Kroon	Noord-Holland	01-07-1996	
Waardtocht	1	Vestas	1650	Hollands Kroon	Noord-Holland	20-02-2003	01-10-2016
Waardtocht	4	Vestas	1750	Hollands Kroon	Noord-Holland	20-02-2003	01-10-2016
Wagendorp	5	Micon	600	Hollands Kroon	Noord-Holland	22-12-1995	01-03-2014
Wagendorp	4	Vestas	3300	Hollands Kroon	Noord-Holland	02-01-2016	
Wagenpad 15	1	Vestas	850	Hollands Kroon	Noord-Holland	13-06-2003	
Warffumerweg	1	EWT	900	Het Hogeland	Groningen	02-01-2015	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Wartumerweg 6	1	Bonus	600	Delfzijl	Groningen	02-01-1998	
Waterkaaptocht	8	Vestas	1750	Hollands Kroon	Noord-Holland	04-06-2003	01-05-2017
Westeinde	7	Neg Micon	900	Hollands Kroon	Noord-Holland	10-02-2006	09-04-2018
Westeinde	7	EWT	900	Hollands Kroon	Noord-Holland	01-08-2018	
Westenwind	3	Enercon	2300	Dalfsen	Overijssel	21-07-2012	
Westenwind	1	Enercon	3000	Dalfsen	Overijssel	21-07-2012	
Westereems	2	Senvion	6150	Het Hogeland	Groningen	02-11-2012	
Westereems	3	Vestas	3000	Het Hogeland	Groningen	02-01-2009	
Westereems	64	Enercon	3000	Het Hogeland	Groningen	07-08-2009	
Westerein 31	1	Neg Micon	750	Waadhoeke	Fryslân	16-02-2005	
Westerein 33	1	Bonus	600	Waadhoeke	Fryslân	02-01-1998	
Westerkerkweg 58	1	Vestas	225	Drechterland	Noord-Holland	13-10-1995	
Westermeerweg 29	1	Neg Micon	750	Noordoostpolder	Flevoland	23-12-2000	
Westerringweg 16	1	Vestas	600	Noordoostpolder	Flevoland	28-09-1996	
Westerse Polder	7	NedWind	500	Hoeksche Waard	Zuid-Holland	02-01-1997	
Westerterpweg 38	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Westerterpweg 38	1	Neg Micon	900	Hollands Kroon	Noord-Holland	16-08-2003	01-06-2015
Westerwirdsleane 6	1	Bonus	250	Waadhoeke	Fryslân	02-01-1995	
Westfrisia	5	Enercon	2350	Medemblik	Noord-Holland	01-02-2019	
Westhavendijk 11	1	Vestas	660	Goeree-Overflakkee	Zuid-Holland	10-11-2000	

VI.xxi Overview of total installed and decommissioned Wind Turbines (cont.21) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Westkapelle	2	Micon	250	Veere	Zeeland	02-01-1995	01-03-2017
Weststad Oosterhout	6	Nordex	2500	Oosterhout	Noord-Brabant	02-01-2008	
WGH Cornelis Douwes turbine 1	1	Vestas	2000	Amsterdam	Noord-Holland	02-07-2008	
Wieringen	2	Micon	225	Hollands Kroon	Noord-Holland	04-05-1996	01-12-2018
Wieringermeer	1	Lagerwey	750	Hollands Kroon	Noord-Holland	02-12-2002	
Wierweg 12	1	Enercon	800	Hollands Kroon	Noord-Holland	02-06-2015	
Wierweg 12	1	Neg Micon	900	Hollands Kroon	Noord-Holland	27-09-2003	01-06-2015
Willem Anna Polder	10	Neg Micon	900	Kapelle	Zeeland	13-12-2002	
Willem Loreweg	1	Bonus	300	Noardeast-Fryslân	Fryslân	02-01-1996	
Windenergie Achtersluispolder turbine 1	1	Vestas	850	Zaanstad	Noord-Holland	02-07-2008	
Windenergie Boekelermeer	1	Enercon	2050	Alkmaar	Noord-Holland	31-03-2010	
Windenergie Hemspoortunnel B.V.	1	Vestas	2000	Zaanstad	Noord-Holland	25-12-2004	
Windkracht 8	1	Enercon	800	Hollands Kroon	Noord-Holland	09-05-2007	
Windkracht VOF	1	Neg Micon	900	Waadhoeke	Fryslân	17-12-2005	01-05-2016
Windmolen Warns	1	Nordtank	150	Súdwest-Fryslân	Fryslân	02-01-1995	
Windpowercentre	1	Siemens	1300	Harlingen	Fryslân	02-01-2000	
Windpowercentre	1	Vestas	850	Harlingen	Fryslân	02-01-2012	
Windpowercentre	2	Nordex	1300	Harlingen	Fryslân	02-01-2000	
Windstroom	6	Enercon	1800	Dronten	Flevoland	15-03-2003	
Windsum B.V.	1	Bonus	300	Het Hogeland	Groningen	02-01-1996	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Windwijzer	1	Lagerwey	80	Medemblik	Noord-Holland	02-09-1994	
Winkelsterlaan	1	Bonus	300	Súdwest-Fryslân	Fryslân	02-01-1996	
Winsum	1	Lagerwey	75	Westerkwartier	Groningen	02-11-1990	
Wintermolen	1	Lagerwey	80	Groningen	Groningen	02-06-1995	
Wintermolen	2	Lagerwey	80	Het Hogeland	Groningen	02-12-1992	
Wintermolen	2	Lagerwey	80	Delfzijl	Groningen	02-01-1992	
Wintermolen	2	Lagerwey	80	Het Hogeland	Groningen	02-10-1993	
Wintermolen	1	Lagerwey	80	Pekela	Groningen	02-10-1993	
Wintermolen	1	Lagerwey	80	Westerkwartier	Groningen	02-06-1995	
Wintermolen	1	Lagerwey	80	Groningen	Groningen	02-06-1995	
Wintermolen	3	Lagerwey	80	Het Hogeland	Groningen	02-11-1992	
Wintermolen	3	Lagerwey	80	Oldambt	Groningen	02-01-1992	
Wintermolen	1	Lagerwey	80	Midden-Groningen	Groningen	02-01-1992	
Wirdsterterp	1	Micon	225	Noardeast-Fryslân	Fryslân	02-01-1995	
Wiske 7	1	Vestas	850	Súdwest-Fryslân	Fryslân	02-10-2013	
Wiske 7	1	Neg Micon	600	Súdwest-Fryslân	Fryslân	13-07-2001	01-01-2013
Wisse Wind	5	Enercon	2300	Tholen	Zeeland	08-04-2011	
Witmarsumerweg-1	1	Bonus	450	Súdwest-Fryslân	Fryslân	02-01-1997	
Witmarsumerweg-2	1	Bonus	600	Súdwest-Fryslân	Fryslân	02-01-1998	
WLF	6	Vestas	225	De Fryske Marren	Fryslân	26-04-1995	01-01-2017

VI.xxii Overview of total installed and decommissioned Wind Turbines (cont.22) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
WNW-Heerenveen	1	Neg Micon	750	Heerenveen	Fryslân	06-11-1999	
Wolfraamweg	2	Lagerwey	75	Heerenveen	Fryslân	02-10-1988	
Wolsumerwei	1	Bonus	300	Súdwest-Fryslân	Fryslân	02-01-1995	
WPN	1	Lagerwey	75	Súdwest-Fryslân	Fryslân	02-10-1990	
Wullink	1	Vestas	850	Zeewolde	Flevoland	18-06-2004	
Wulpweg	1	Neg Micon	1000	Zeewolde	Flevoland	25-12-2004	
Wulpweg	16	Vestas	850	Zeewolde	Flevoland	24-09-2002	
WUR	6	Neg Micon	1000	Lelystad	Flevoland	01-02-2005	
WWC	2	Lagerwey	80	Medemblik	Noord-Holland	02-02-1995	
WWC	2	Lagerwey	75	Medemblik	Noord-Holland	02-05-1988	
Xander Energy	1	Neg Micon	1000	Leeuwarden	Fryslân	22-04-2006	
Zaanse E.K.	1	Lagerwey	80	Zaanstad	Noord-Holland	02-10-1994	
Zeeasterweg 14	1	Vestas	850	Lelystad	Flevoland	08-10-2003	
Zeeasterweg 16	1	Vestas	600	Lelystad	Flevoland	08-06-1996	
Zeeasterweg 23	1	Vestas	660	Lelystad	Flevoland	05-03-1998	
Zeebiestocht	10	Enercon	2300	Dronten	Flevoland	17-11-2007	
Zeebiesweg 50	1	Vestas	660	Lelystad	Flevoland	16-05-2000	
Zeedijk	1	Enercon	2350	Borsele	Zeeland	02-03-2015	
Zeshoek	1	Lagerwey	3000	Lelystad	Flevoland	02-10-2013	
Zeshoek	1	Lagerwey	3000	Lelystad	Flevoland	02-02-2014	

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Zierikzee	3	Senvion	3400	Schouwen-Duiveland	Zeeland	16-12-2014	
Zodewiwa	1	Neg Micon	1000	Zeewolde	Flevoland	22-12-2004	
Zodewiwa	3	Neg Micon	1000	Zeewolde	Flevoland	22-12-2004	
Zoekweg	1	Lagerwey	750	Steenbergen	Noord-Brabant	02-05-1999	
Zoetermeer Siemens	1	Enron	1500	Zoetermeer	Zuid-Holland	01-10-2000	01-01-2014
Zonzeel	2	Lagerwey	80	Drimmelen	Noord-Brabant	02-05-1995	
Zuiderdijkweg 11	1	Vestas	850	Hollands Kroon	Noord-Holland	24-01-2003	
Zuiderkruisweg Leeuwarden	1	Enercon	800	Leeuwarden	Fryslân	02-06-2016	
Zuidermeerweg	1	Bonus	600	Noordoostpolder	Flevoland	02-01-1998	
Zuidermeerweg 39	1	Nordtank	500	Noordoostpolder	Flevoland	20-05-1995	
Zuidermiddenweg 13	1	Neg Micon	750	Noordoostpolder	Flevoland	07-12-2000	
Zuiderweg 4	1	Vestas	850	Zaanstad	Noord-Holland	01-02-2002	
Zuiderzeehaven	4	Enercon	3000	Kampen	Overijssel	02-08-2015	
Zuidhorn	1	Lagerwey	75	Westerkwartier	Groningen	02-07-1990	
Zuidwal	5	Vestas	3000	Rotterdam	Zuid-Holland	02-01-2015	
Zuidwal	5	Neg Micon	2000	Rotterdam	Zuid-Holland	02-02-2005	01-01-2014
Zuidwest Friesland	1	Lagerwey	80	Súdwest-Fryslân	Fryslân	02-11-1994	
Zuidwest Friesland	1	Lagerwey	80	Súdwest-Fryslân	Fryslân	02-07-1994	
Zuidwest Friesland	1	Lagerwey	80	Súdwest-Fryslân	Fryslân	02-06-1995	
Zuidwesterringweg	1	Nordtank	500	Noordoostpolder	Flevoland	02-10-1996	

VI.xxiii Overview of total installed and decommissioned Wind Turbines (cont.23) [7]

Project	#	Merk	kW	Gemeente	Provincie	Start datum	Eind datum
Zuigerplasdreef 2	1	Vestas	600	Lelystad	Flevoland	12-10-1996	
Zwartemeerweg 64	1	Vestas	850	Noordoostpolder	Flevoland	30-12-2000	
Zwartenbergseweg	5	Vestas	2000	Etten-Leur	Noord-Brabant	02-06-2013	
Zwinweg	1	Enercon	800	Hollands Kroon	Noord-Holland	24-02-2011	

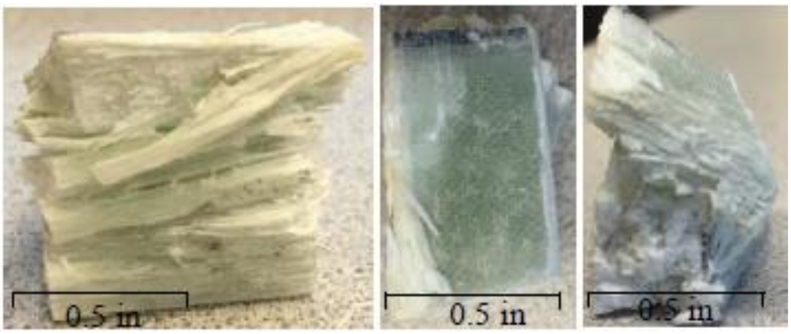
Appendix VII W.T. blades in pavement application

VII.i Sample material (epoxy/glass fiber) provided by TPI [13]

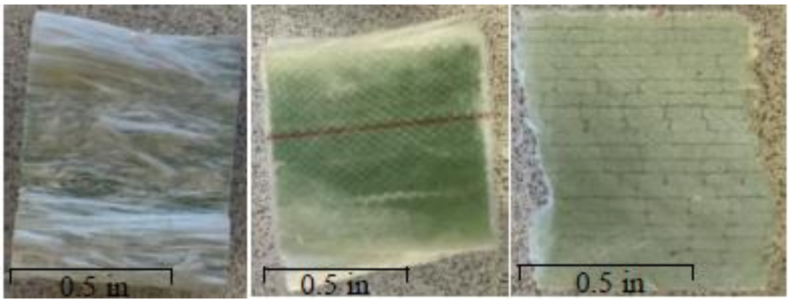
Aggregate produced with manual process [13]

Material strips cut by wet saw [13]

VII.ii Appendix Shearing of the shredded granulates



Shearing of the fiber glass granulates [13]

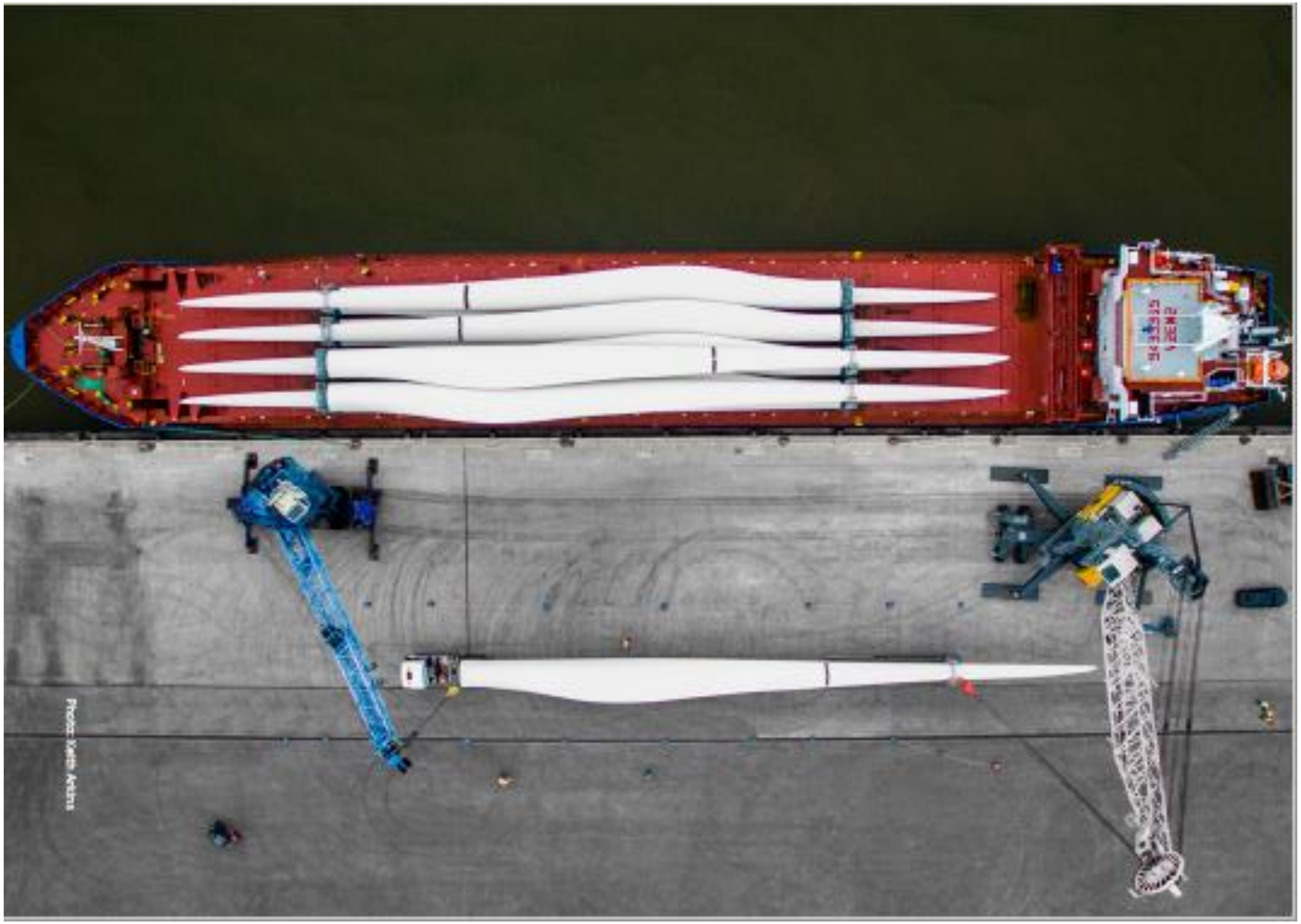


Shearing against the fiber glass granulates [13]

Manual cutting (80 hours) is clearly not the best solution of producing the granules on a large scale. Other equipments like rock crusher and chipper were tried to see if the production of the granules could be improved. Chipping showed the most promising results, producing long strips and slabs of the material. All of this is illustrated in figure 10 [13].

Rock crusher, Crushed material and Chipped material (third picture from left) [13]

Appendix VIII Transportation by sea [32]



Appendix IX Landfill tax and prohibition Netherlands vs Europe [33]

CEWEP

Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

COUNTRY	LANDFILL TAX IN €/T	LANDFILL TAX PLANNED	LANDFILL BAN IMPLEMENTED	LANDFILL BAN PLANNED
EU 28	24 EU Member States have a tax (AT, BE, BG, CZ, DK, EE, EL*, ES, FI, FR, HU, IE, IT, LT,LU**, LV, NL, PL, PT, RO, SE, SL, SK, UK), as well as Norway and Switzerland. 4 EU Member States do not have a landfill tax (CY, DE, HR, MT). Tax rates vary from 3€/t (LT) to more than 100€/t (BE). *: the Greek landfill tax was suspended for 2017 **: a municipal tax is applied in Luxembourg		18 EU Member States adopted a ban** (AT, BE, DE, DK, EE, FI, FR, HU, HR, LT, LU, NL, PL, RO, SE, SL, SK, UK), as well as Norway and Switzerland. 10 EU Member States do not have a ban** (BG, CY, CZ, EL, ES, IE, IT, LV, MT, PT). **landfill ban: stream banned from landfilling additionally to the requirements of Directive 1999/31/EC on the landfill of waste	
AUSTRIA	87€/t since 2006 - Tax exists since 1999 - Tax depends on composition of waste and standard of the landfill. - Residues from incineration and co-incineration plants are exempted from landfill tax. - Landfill tax increased more than 50% from 2001 and 2010.	Adjustment of prices to annual consumer price index	Introduced in 1996, full implementation on 1.1.2004 with local exemptions until 31.12.2008. Bans waste with TOC > 5% with exceptions for: - mechanical-biological treatment waste with a calorific value > 6600 kJ/kg dry substance - mechanically treated waste with a calorific value > 6600 kJ/kg dry substance and TOC > 8%	
BELGIUM, BRUSSELS	There are no landfills in Brussels region			
BELGIUM, FLANDERS	101.91 €/t for combustible waste landfilled in inorganic industrial waste landfill 56.05 €/t for non-combustible waste - average cost (pre-tax) in 2016: 58€/t for household and similar waste, 44€/t for industrial waste Reference year: 2017 unless indicated otherwise	Adjustment of prices to annual consumer price index	- Since 1998, ban on separately collected waste. - Since 2000, ban on combustible waste (TOC > 6% and LOI > 10%). - Since 2007, ban on biodegradable waste.	

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IX.i Landfill tax and prohibition Netherlands vs Europe (cont. 1) [33]

CEWEP Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

COUNTRY	LANDFILL TAX IN €/T	LANDFILL TAX PLANNED	LANDFILL BAN IMPLEMENTED	LANDFILL BAN PLANNED
BELGIUM, WALLONIA	113.01 €/t for general waste 62.16 €/t for non-combustible waste Reference year: 2017	Adjustment of prices to annual consumer price index	- Since 2004, ban on combustible waste (TOC > 6%)	
BULGARIA	40 BGN per tonne in 2017 (20€) 45 BGN per tonne in 2018 (23€) 57 BGN per tonne in 2019 (30€) 95 BGN per tonne in 2020 and following years (50€)		No ban.	
CROATIA	No tax.	A fee is encouraged by the waste management plan for 2017-2022, but not applied yet.	Limit on amount of biodegradable waste that can be deposited in the landfill (50% of amount deposited in landfill from 1st January 2017, 35% by 31st December 2020)	
CYPRUS	No tax.		No ban.	
CZECH REPUBLIC	500 Kc per tonne (20€) for municipal waste. Additional fees are applied for other types of waste. Furthermore, a "risk fee" is added for hazardous waste. Reference: law of 1992, still applied in 2017	According to the waste management plan 2015-2024, the tax should be adjusted in order to divert waste higher up the hierarchy.	No ban.	2024: landfilling of mixed municipal waste will be banned Source: waste management plan 2015-2024
DENMARK	Tax in place since 1987. 475 DKK per tonne (63.3€) before VAT (79€ VAT inc.). Reference: since 2010, still valid in 2017		Since 1997, ban on recycling and combustible waste (3% TOC in 2011).	
ESTONIA	Since 1990. 29.84€ per tonne in 2017		Ban on untreated waste since 2004 and unsorted MSW since 2008.	

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IX.ii Landfill tax and prohibition Netherlands vs Europe (cont. 2) [33]

CEWEP Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

COUNTRY	LANDFILL TAX IN €/T	LANDFILL TAX PLANNED	LANDFILL BAN IMPLEMENTED	LANDFILL BAN PLANNED
FINLAND	70€ per tonne in 2017		Ban on organic waste (TOC > 10 %) in application since 1st January 2016. Ban on construction and demolition waste will enter into force on 1st January 2020.	
FRANCE	150€ per tonne in 'non-authorized' landfills A: 32 €/t in 'authorized' + ISO 14001 landfills B: 23 €/t in 'authorized' landfills with 75% energy recovery from captured biogas C: 32 €/t in 'authorized' bioreactor landfill cells with biogas recovery B + C – 15 €/t Other 'authorized' landfills: 40€/t Reference year: 2017	Taxes are updated yearly.	Ban on untreated waste since 2002. Ban on source separated waste collected for recycling. Ban on waste from municipalities which do not have source separation schemes.	
GERMANY	No tax.		Landfill ban introduced with an administrative regulation (TASi) in 1993 on untreated waste with TOC > 3 %, full implementation since 1.6.2005. There are exceptions for: - mechanical-biological treatment waste with a calorific value > 6600 kJ/kg dry substance - mechanically treated waste with a calorific value > 6600 kJ/kg dry substance and TOC > 8%	

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IX.iii Landfill tax and prohibition Netherlands vs Europe (cont. 3) [33]

CEWEP Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

COUNTRY	LANDFILL TAX IN €/T	LANDFILL TAX PLANNED	LANDFILL BAN IMPLEMENTED	LANDFILL BAN PLANNED
GREECE	Landfill tax since 1.1.2014. **This fee was suspended from 1.1.2017 to 31.12.2017.** From 35€/t in 2014, increases by 5€/t every year up to 60€ maximum. This fee does not apply to residues of waste treatment processes.	In 2017, The European Commission called Greece to "Properly enforce and gradually increase landfill taxes to phase-out landfilling of recyclable and recoverable waste."	No ban.	
HUNGARY	Landfill tax since 1.1.2013. Fee started at 6,000 HUF (19.35€) in 2013, planned to be raised yearly to maximum 12,000 HUF (38.7€/t) in 2016. In 2017, the fee is still 6,000 HUF (19.35€).		Since 2002 on untreated waste. Since 2003 on hazardous waste streams including waste tyres, shredded rubber and partially organic wastes.	
IRELAND	75€ per tonne since 1.7.2013.		No ban. Ireland aims to reduce to 0% direct disposal of unprocessed residual waste to landfills from 2016 onwards, and to achieve the Landfill Directive target on biodegradable waste by 2020.	

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IX.iv Landfill tax and prohibition Netherlands vs Europe (cont. 4) [33]

Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

<table>
<tr>
<td>ITALY</td>
<td>Landfill tax varies between regions, from 5.2€ to 25.82€ per tonne.

Rates in 2017*:
<table>
<tr><th>Region</th><th>Rate(s)</th></tr>
<tr><td>Aosta Valley</td><td>18 € per tonne</td></tr>
<tr><td>Basilicata</td><td>25 € per tonne, with up to 90% reduction based on separate collection level</td></tr>
<tr><td>Campania</td><td>10.3 € per tonne
5.2 € per tonne if pre-treated</td></tr>
<tr><td>Emilia-Romagna</td><td>15 € per tonne</td></tr>
<tr><td>Friuli-Venezia Giulia</td><td>25.82 € per tonne</td></tr>
<tr><td>Lazio</td><td>10.329 € per tonne if collected separately or from mechanical separation
15.493 € per tonne otherwise</td></tr>
<tr><td>Liguria</td><td>14.42 € per tonne</td></tr>
<tr><td>Lombardy</td><td>15 € per tonne</td></tr>
<tr><td>Marches</td><td>20 € per tonne</td></tr>
<tr><td>Piedmont</td><td>12 € per tonne</td></tr>
<tr><td>Puglia</td><td>25.82 € per tonne</td></tr>
<tr><td>Sardinia</td><td>25.80 € per tonne or 18 € for stabilised waste.
Up to 70 % reduction based on the separate collection level.</td></tr>
<tr><td>Tuscany</td><td>15 € per tonne</td></tr>
<tr><td>Veneto</td><td>25.82 € per tonne</td></tr>
</table>
*: data missing for some regions</td>
<td>In many regions, the tax is adopted yearly.</td>
<td>No ban*.

*A ban on waste with Calorific value > 13,000 kJ / kg was introduced in the 2003 landfill law, for an implementation by 2007. This implementation was delayed 6 times, until 2016/2017 when the ban was abrogated.</td>
<td></td>
</tr>
</table>

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IX.v Landfill tax and prohibition Netherlands vs Europe (cont. 5) [33]

CEWEP Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

COUNTRY	LANDFILL TAX IN €/T	LANDFILL TAX PLANNED	LANDFILL BAN IMPLEMENTED	LANDFILL BAN PLANNED
LATVIA	Landfill tax in application since 1991. 25€ per tonne in 2017 35€ per tonne in 2018 43€ per tonne in 2019 50€ per tonne in 2020		No ban.	
LITHUANIA	3€ per tonne in 2017 5€ per tonne in 2018 21.72€ per tonne in 2019 27.51€ per tonne from 2020		Since 2000, ban on tires (unless used as construction material) and biodegradable waste from gardens, parks and green areas. Since 1.1.2013, ban on untreated municipal waste.	
LUXEMBOURG	No national tax. An 8€ per tonne fee is applied by the municipality who owns the only landfill in Luxembourg.		Ban on untreated MSW and organic waste (TOC > 5%).	
MALTA	No tax.		No ban.	
NETHERLANDS	Introduced in 1995, repealed in 2012 and reintroduced in 2015. 13.11€ per tonne in 2017	Tax is adjusted yearly.	Ban since 1995 on 35 waste streams, including combustible and biodegradable waste (TOC > 5%). In 2017, it includes over 60 streams.	
NORWAY	Introduced in 1999, repealed on 1.1.2015		Ban on biodegradable waste and waste with TOC > 10% and LOI > 20% introduced on 1.7.2009	
POLAND	140 PLN per tonne in 2018 (33 €) 170 PLN per tonne in 2019 (40€) 270 PLN per tonne from 2020 (64€)		Since 1.1.2013, ban on biodegradable waste collected separately. Since 1.1.2016, ban on combustible waste with > 5 % TOC, >8% LOI, Calorific value > 6MJ/kg	
PORTUGAL	Tax introduced in 2007. 2017: 7.7 € per tonne 2018: 8.8 € per tonne 2019: 9.9 € per tonne 2020: 11 € per tonne		No ban.	

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IX.vi Landfill tax and prohibition Netherlands vs Europe (cont. 6) [33]

Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

COUNTRY	LANDFILL TAX IN €/T	LANDFILL TAX PLANNED	LANDFILL BAN IMPLEMENTED	LANDFILL BAN PLANNED
ROMANIA	Tax introduced on 1.1.2018. 80 RON per tonne in 2017 (17€) 120 RON per tonne in 2018 (26€)		No ban.	
SLOVAKIA	Tax introduced on 1.1.2014. Rates since 2016: 9.96 € per tonne of MW collected in less than 4 separate fractions 5.98 € per tonne of MW collected in 4 separate fractions 4.98 € per tonne of MW collected in 5 separate fractions		Since 1.7.2016, ban on sorted biodegradable kitchen and restaurant waste, biodegradable municipal waste from gardens, parks and cemeteries.	
SLOVENIA	Tax introduced in 2001. Latest update: 2014. 11 € per tonne Still in application in 2017		Since 2011, ban on Calorific value > 6 MJ/kg, TOC > 5%, AT_4 > 10mg O_2 / g dry matter. This ban also includes mixed municipal waste and separately collected waste.	

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IX.vii Landfill tax and prohibition Netherlands vs Europe (cont. 7) [33]

Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). “No ban” means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. “No tax” refers only to taxes/fees for landfilling MSW.

<table>
<tr><th>COUNTRY</th><th>LANDFILL TAX IN €/T</th><th>LANDFILL TAX PLANNED</th><th>LANDFILL BAN IMPLEMENTED</th><th>LANDFILL BAN PLANNED</th></tr>
<tr><td>SPAIN</td><td>
<table>
<tr><th>Region</th><th>Tax</th></tr>
<tr><td>Cantabria</td><td>41.19 € / t</td></tr>
<tr><td>Castilla y León</td><td>7 € / t (non-recoverable)
20 € / t for recoverable (taking into account the proportion of recoverable fractions)</td></tr>
<tr><td>Catalonia</td><td>In place since 2003.
- 30 € / t in 2017
- 35.6 € / t in 2018
- 41.3 € / t in 2019
- 47.1 € / t in 2020</td></tr>
<tr><td>Extremadura</td><td>12 € / t</td></tr>
<tr><td>La Rioja</td><td>12 € / t</td></tr>
<tr><td>Valencia</td><td>41.3 € / t in 2019</td></tr>
</table>
</td><td></td><td>No ban.</td><td></td></tr>
<tr><td>SWEDEN</td><td>Since 2000.

Fee since 2015: 500 SEK (50€)

Still in application in 2017.</td><td></td><td>Since 2002, ban on sorted combustible waste.
Since 2005, ban on organic waste.</td><td></td></tr>
<tr><td>SWITZERLAND</td><td>- Inert waste: 5CHF / tonne (4.3€)
- Stabilized waste, bottom ash, construction waste: 16 CHF / tonne (13.7€)
- Underground landfill in a foreign country: 22 CHF / tonne (18.9€)

Rates in application since 1.1.2017</td><td></td><td>Ban on untreated and combustible waste since 2000.</td><td></td></tr>
</table>

IX.viii Landfill tax and prohibition Netherlands vs Europe (cont. 8) [33]

CEWEP Notes: Unless specified, this information relates to Municipal Solid Waste (MSW). "No ban" means no additional measure compared to the requirements of Directive 1999/31/EC on the landfill of waste. "No tax" refers only to taxes/fees for landfilling MSW.

COUNTRY	LANDFILL TAX IN €/T	LANDFILL TAX PLANNED	LANDFILL BAN IMPLEMENTED	LANDFILL BAN PLANNED
UNITED KINGDOM	Tax introduced in 1996. **England, Wales and Northern Ireland** *Rates from 1st April 2017:* £86.10 / tonne (standard rate) £2.70 / tonne (lower rate) *Rates from 1st April 2018:* £88.95 / tonne (standard rate) £2.80 / tonne (lower rate) **Scotland** Since 1st April 2015, Scotland can adopt its own landfill tax. In 2017, the rate was the same as the rest of the UK.		**Scotland** Ban on source-separated waste since 2014, coupled with mandatory source separation of food waste for businesses producing > 5 kg of food waste per week. **Northern Ireland** Since 1st April 2015, ban on separately collected food waste coupled with mandatory source separation of food waste for businesses producing > 5 kg of food waste per week.	**Scotland** Ban on biodegradable waste by 2021. **Wales** Ban foreseen on separately collected waste.

Glossary:

TOC – Total Organic Carbon

LOI – Loss on Ignition

DOC – Dissolved Organic Carbon

EWC – European Waste Code

No ban – No additional waste stream banned compared to the requirements of the Landfill Directive.

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