17th International Conference on Environmental Science and Technology

Athens, Greece, 1 to 4 September 2021

Technological solutions for giving a new life to power plants of alternative energy: social, economic, and environmental assessment of end of life scenarios

AMBROSINO C. [1]**, GIAQUINTO D.**[1]**, MASELLI G.**[2]**, NESTICÒ A.**[2]**, ZARRA T.**[1]**, BELGIORNO V.**[1]**, NADDEO V.**[1]

[1]Sanitary Environmental Engineering Division (SEED), Department of Civil Engineering, University of Salerno, via Giovanni Paolo II, Fisciano, SA, Italy

[2]Project Evaluation Laboratory (PEL) Department of Civil Engineering, University of Salerno, 8 via Giovanni Paolo II, Fisciano, SA, Italy

*corresponding author: Carlo Ambrosino
e-mail: karloambrosino@gmail.com

Abstract

The resources on the planet are not unlimited and special attention has been paid to alternative energies in recent years.

Alternative (or renewable) energy are all those energy sources that do not come from fossil fuels (coal, oil and natural gas). To date, wind and solar energy are the main sources of renewable energy on which huge investments has been made in recent years. However, many of these plants are no longer functional and need to be disused or upgraded.

The aim of the following study is to show a technical and economic analysis carried out on some alternative energy plants, focusing on the social, economic and environmental aspects.

In particular, the different possible scenarios were analyzed, in which the principles of reuse and recycling were applied, where the different plants from renewable sources were given a new life.

Keywords: renewable energy, natural resource conservation, solar energy, wind energy, life cycle economy

1. Introduction

In the last 30 years we have seen how the world is increasingly moving towards the use of renewable and sustainable energy to achieve the objectives of Sustainable Development. In recent years, the evolution of the energy transition has taken place more significantly than in previous years, in fact, renewable energies have moved to the center of the global energy landscape. Increased energy consumption, technological advances and cost reductions have contributed to a faster development of the use of renewable energy than any other energy source, while the speed of energy transformation is uncertain (Abdelilah et al).

The study identified the capacity, in terms of GW, of all installed renewable energies (Figure 1).

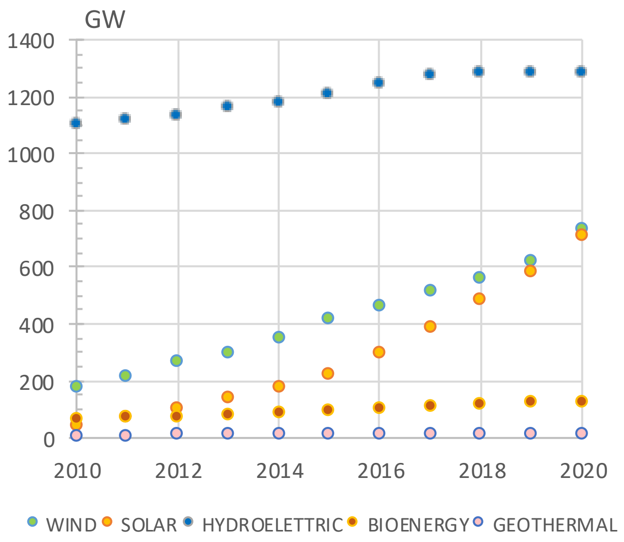

Figure 1: Installed capacity of the various renewable energies in the world in 2010-2020 (Whiteman et al)

2. End of life assessment

Four scenarios have been hypothesized for the end of life of wind turbines and photovoltaic panels:

- <u>Disassembly:</u> The photovoltaics consists in uninstalling and disassembling the panels, inverters, electrical panels, transformers, and cables takes place from the system while, for a wind farm, it consists of the disassembly of the 3 blades, the turbine, the demolition of the foundation and the restoration of the soil with hydro Semin.
- <u>Transport:</u> Heavy Duty Trucks greater than 16 tons were used. In photovoltaics we have a first route from the plant site to the RAAE collection center equal to 50 km and a second route from the RAAE centers to

the treatment centers equal to 50 km. For a wind turbine, three routes have been hypothesized, the first from the site to the landfill (50 km) for materials such as concrete, the second from the plant to reuse/regeneration (100km) and the third from the regeneration plant to the recycling plant (100 km).

- Reuse/Regeneration: The reuse activities concern the upgrading of a share of the disused panels during the period considered, which is assumed in the percentage of 5% (ENEA). For wind Turbines, used turbines that are still functioning or regenerated and put on the market are sold 50% of the new price (Ortegon et al).
- Recycling and recovery treatment: The FRELP process has been used in photovoltaic, which is an upcycle treatment that is that type of treatment with a high technological content, able to guarantee higher value outputs and which includes 3 processes: Mechanical, Thermal, Chemical (Latunussa et al 2016a). For the analysis of a wind turbine, it has been hypothesized that all components consisting of materials such as steel, iron, aluminum, copper are easily recoverable and economical revenue can be drawn, while for wind turbines that consist of composite materials (glass fibers, epoxy resin and plastic) 50% is sent to incineration and the other 50% to landfill (Razdan et al).

Three main effects are evaluated for each hypothesis of end of life scenario:

- *The Social Effects*: The Employment Factor methodology has been used (Felici et al. 2015). This employment factor estimate uses a coefficient called EF, which measures the employment intensity of the technology, expressed in the number of employees per year per MW installed. Each activity corresponds to a different coefficient (ENEA).
- *The economic effects:* In Photovoltaic, are evaluated by the ENEA document and two Decommissioning plans of a 19.22 MWp photovoltaic system in the municipality of Ferrandina (Matera) and a 2.19 MWp photovoltaic system in the municipality of Collesalvetti (Livorno). For Wind turbine has been considered the decommissioning plan for the 71.4 MW wind farm in the municipality of Montemilone of the company COGEIN ENERGY and the decommissioning plan for the 45 MW wind farm in the municipality of VENOSA. The model of the 4.2 MW VESTAS VP-150 turbine was taken as a reference for the study.
- *The Environmental Effects*: the climate-altering gases carbon dioxide (CO2), particulate matter (PM2.5) and volatile organic compounds (NMVOC) were taken into consideration, respectively for the categories of environmental pressures: Climate change, Particulate formation, Formation of photochemistry of Ozone by ISPRA SINANET data for emissions in the transport phase. For the Treatment and Reuse phases have been used (Huang et al. 2017, Latunussa et al. 2016b, Ardente et al. 2019, Lunardi et al. 2018, Faircloth et al. 2019, Razdan et al 2019).

2.1. Summary of photovoltaics end of life

Social summary: the greatest contribution is made in the, upgrading and sale of used panels (1,47 employees/MW) and transport operations (0,98 employees/MW).

Economic summary: within the hypothesis considered here, the scenario with the highest revenues is the reuse and regenerated phase would contribute to an important extent to provide the greatest contribution (236.476 €/MW), followed by the revenues of the sale of Second Raw Materials by recycling (21.207 €/MW), also considering the most innovative and performing treatment systems that allow high percentages of recovery and with a certain degree of purity of the recovered materials.The most expensive scenario was the disassembly of PV panels, which is estimated to a ccost around 29.454 €/MW, due only to the quotas of workers' wages and the cost of landfilling, followed by transport determined by the large number of loads of heavy trucks (12.582 €/MW).

Environmental summary: most of the impact of the decommissioning phase is due to transport operations and metal incineration and recovery processes. In general, the impacts of an upcycle recycling process are lower when compared to generic treatment processes (incineration, landfill), for abiotic exhaustion (minerals), for the recovery of important materials such as metallic silicon, copper, and silver, and for energy saving.

2.2. Summary of Wind turbines end of life

This illustrates the outcome of the economic, employment and environmental assessment of the end-of-life system of a 4.2 MW Vestas V-150 wind turbine, despite the analysis having several elements of uncertainty.

The Social effects: the greatest contribution is made in the dismantling (18 employees /turbine), recycling process (18 employees/turbine) and transport (16 employees/turbine).

The Economics effect: The scenario in which revenues are generated is the reuse for wind, due to the sale of regenerated turbines, where there is a gain of 624.000 €/MW. The most expensive scenario was the disassembly of the wind farm, which is estimated to cost around 165.964 €/MW, due to multiple cost items, followed by transport (9.919 €/MW) and recycling (7.836 €/MW).

The Environmental effects: most of the impact of the divestment phase is due to transport operations, metal incineration and recovery processes and above all to the landfill for land use that is occupied by blades.

3. Comparison

Analyzing the end-of-life scenarios of photovoltaics and wind turbines, the two renewable energy sources were compared from an economic, social, and environmental point of view.

The Economics effect: The economic values were normalized going from €/turbine for wind power and from €/t for photovoltaics, to € per MW. Wind power has proven to be the energy with higher total Revenues (440.281 €/MW) than photovoltaics (215.646 €/MW). and everything is shown in the following graphs (Figure 2):

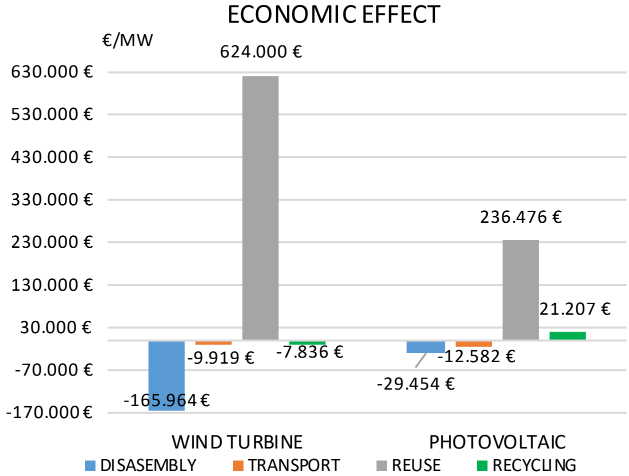

Figure 2: summary regarding the economic effects of the 4 wind and photovoltaic end-of-life scenarios

<u>The Employment effects:</u> Similarly, the numbers of the workers per MW in the various phases, have been added together. It is found that the end of life of wind requires more workers (14.05 employees/MW) than photovoltaics (2.95 employees/MW) (Figure 3):

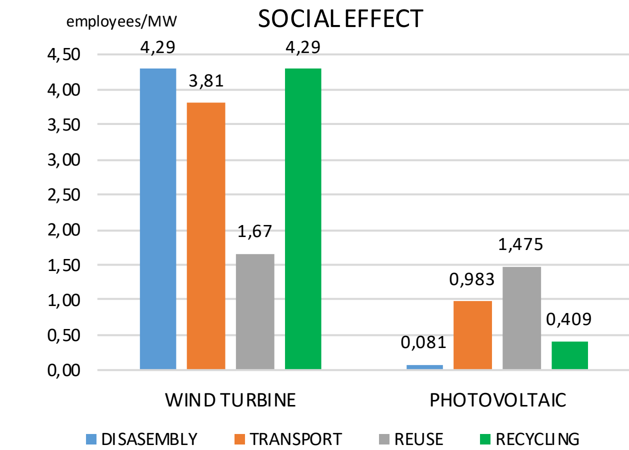

Figure 3: summary regarding the social effects of the 4 wind and photovoltaic end-of-life scenarios

The Environmental effects: After normalizing the environmental data to the MW and summing up the data relating to all the scenarios, it is found, as can be seen from the following graphs in Figure 4, that the environmental pressures due to the photovoltaic end (77%) are far higher than those due to the end of life of the wind (23%).

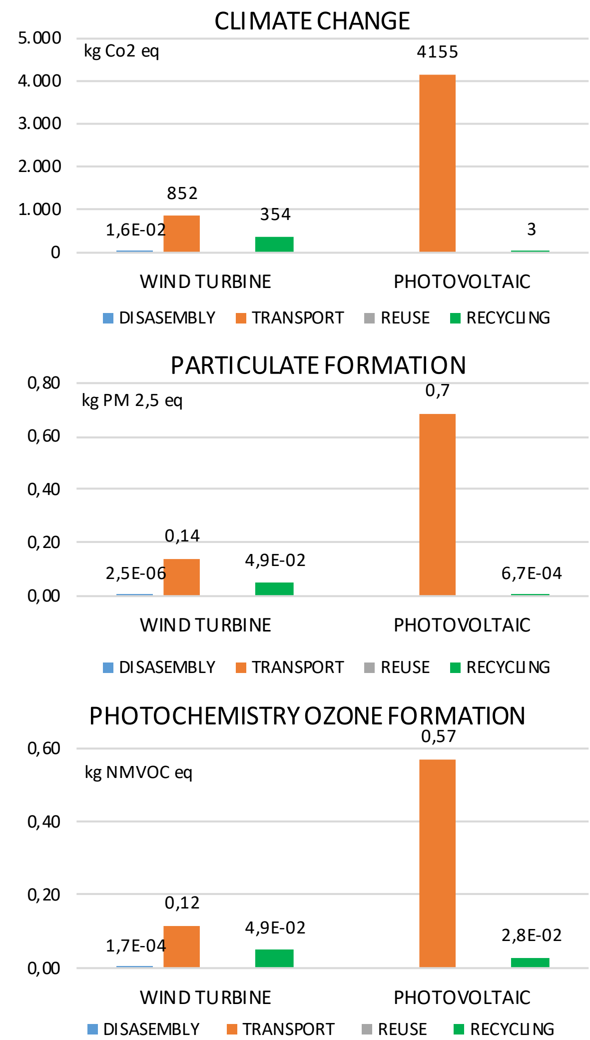

Figure 4: Environmental IMPACTS concerning the 4 end-of-life scenarios for wind power and photovoltaics

In conclusion, from the summary indicated above, the overall end of life of wind power brings benefits from an economic, occupational, and environmental point of view. It would therefore be desirable to incentivize the reuse and recycling of wind turbines to enjoy the benefits, thus increasing the secondary market and re-entering the circular economy.

4. Conclusions

From the study of the end-of-life analysis of photovoltaics in the coming years we will have many photovoltaic systems to divest that will bring great problems in the management of the flow of photovoltaic waste. Some of them will be reused and resold as used panels where a profit can be made. This allows to extend the useful life of the panel but postpones the problem of waste management. Nowadays recycling plants are composed of low-consumption technologies but with a yield of recycled materials not efficient enough to promote the circular economy.

A solution has already been presented by the company SASIL with the FRELP project which is a process with high energy consumption but with high output product yields. With purer recycled materials, it is possible to promote the production of recycled photovoltaics for the future and to easily manage the waste stream of photovoltaics, implementing this solution.

About the end of life of wind, the problems are mainly due to the size of wind turbines but above all to composite materials of blades that are not highly recyclable. Wind blades are generally incinerated without environmental benefits or landfill, although this process is prohibited in many countries such as Germany. The disposal of wind turbines in landfills would fill all landfills and thus occupy and consume a large part of the soil.

The solutions to avoid these processes can be reuse in other areas of blades. They separate and cut into various parts and then reuse in the field of construction, in furniture.

Other solutions may be the reuse of glass fibres (produced by grinding blades) which mixed with concrete, would increase the mechanical strength of the latter.

References

Abdelilah Y., Bahar H., Criswell T., Bojek P., Briens F. and Le Feuvre P., (2020), Renewables - Analysis and forecast to 2025, 172, IEA.

Ardente F., Latunussa C. E. L. and Blengini G. A., (2019), Resource efficient recovery of critical and precious metals from waste silicon PV panel recycling. Waste Management 91, 156–167.

Corrias P., Ciorba U. and Felici B.,(2021), Il fine vita del fotovoltaico,61, ENEA.

Faircloth C. C., Wagner K. H., Woodward K. E., Rakkwamsuk P. and Gheewala S. H., (2019), The environmental and economic impacts of photovoltaic waste management in Thailand. *Resources, Conservation and Recycling* **143**, 260–272.

Felici B, Corrias P., Baldissara B., Amerighi O., Tricol C., (2015), l’impatto occupazionale delle fonti energetiche rinnovabili in italia: il fotovoltaico, 37, ENEA.

Huang B., Zhao J., Chai J., Xue B., (2017), Environmental influence assessment of China’s multi-crystalline silicon (multi-Si) photovoltaic modules considering recycling process. Solar Energy 143, 132-141.

Latunussa C., Ardente F., Blengini G., Mancini L., (2016b), Life Cycle Assessment of an innovative recycling process for crystalline silicon photovoltaic panels. Solar Energy Materials and Solar Cells 156,101-111.

Latunussa C., Mancini L., Blengini G., Ardente F., Pennington D., (2016a), Analysis of material recovery from photovoltaic panels. EUR 27797.

Lunardi M., Alvarez-Gaitan J., Bilbao J. and Corkish R., (2018), Comparative Life Cycle Assessment of End-of-Life Silicon Solar Photovoltaic Modules. *Applied Sciences* **8**, 1396.

Ortegon K., Nies L. F., and Sutherland J. W., (2013) Preparing for end of service life of wind turbines. *Journal of Cleaner Production* **39**, 191–199.

Razdan P. and Garrett P., (2019), Life Cycle Assessment of Electricity Production from an onshore V150-4.2 MW Wind Plant,134, VESTAS.

Whiteman A., Akande D., Elhassan N., Escamilla G., Lebedys A. and Arkhipova L., (2021), Renewable Capacity Statistics IRENA