Master Thesis

Enel Green Power Spain's new warehouse for large wind power components

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Abstract: Enel Green Power Spain (EGPE) has only one warehouse in the Iberian Peninsula, located in As Pontes, Galicia. As a result of the project to be carried out in Teruel after the dismantling of the old Andorra thermal power plant, it is proposed to take advantage of the available surface area to install a new warehouse for large wind power components in order to optimize the logistics related to the maintenance of the wind farms in the area. In the project, the warehouse has been designed considering the failure rate of the components of the nearby wind farms. Thanks to the economic and environmental study carried out, it has been proven than the project would allow to reduce costs as well as the carbon footprint associated to the transport of components.

Keywords: Enel Green Power, large wind turbine component, warehouse, logistics, carbon footprint

1. Introduction

Enel Green Power España (EGPE) is the renewable energy subsidiary of Endesa, one of the leading companies in the energy sector in Spain. It currently has 9,293 GW (as of 01/31/2023) installed in Spain among wind, solar and hydroelectric technology.[1]

In terms of wind technology, EGPE's fleet consists of 105 operating wind farms totaling 2,882 MW and is expected to continue to grow in the coming years. This technology has many advantages, mainly that it is obtained from a renewable source such as wind and that it does not emit greenhouse gases in the generation of electricity. However, the operating costs and carbon footprint of wind farms come mainly from wind turbine maintenance. Major corrective maintenance involves high costs due to the replacement of large components and the associated logistics, which also entails a large carbon footprint due to long-distance transportation.

Moreover, Enel Green Power has plans to carry out many other projects of wind farms, which are shown in ***Figure 1.***

Figure 1 Major wind farm projects.

Therefore, given the clear need that the company will experience in terms of logistics, this project seeks to optimize the logistics of large wind components in order to reduce costs and pollutant gas emissions.

2. State of the Art

Currently, Enel Green Power España [1] has only one large component warehouse on the Iberian Peninsula, the As Pontes Central Warehouse, located in Galicia. In Figure 2 is shown that many wind farms are located hundreds of kilometers away from EGPE's Central Warehouse in Galicia, which has made the company spend too much money in the logistics related to large correctives.

Figure 2 Enel Green Power's wind farms in Spain.

3. Objectives

The objectives of this project are the following:

- Design of the warehouse.

The first objective of the project is to evaluate the possibility of using one of the warehouses of the former Andorra thermal power plant as a warehouse for large components, considering the failure rate of the wind turbines belonging to nearby wind farms and the dimensions of the main components of the wind turbines. In addition, it is sought to establish the necessary measures for the reconditioning of this warehouse.

- Economic evaluation

The second objective is to determine the economic impact of the project. For this purpose, the savings in logistics due to the reduction of transport distances for large components will be evaluated, as well as the costs associated with the project, to determine its profitability.

- Environmental assessment

The final objective of the project is to evaluate the impact of the project on greenhouse gas emissions resulting from the logistics related to the transport of large wind components. To this end, a comparison will be made of the current logistics and the logistics in the event of carrying out the project, considering both transport emissions and those derived from the warehouse itself.

4. Materials and Methods (Methodology)

The project has been carried out according to the following phases:

1. Obtaining the necessary data to carry out the project, including:
    a. Failure rate of the different components per farm.
    b. Distances from each wind farm to the current Central Warehouse and to the new warehouse.
    c. Transports used for the major components.
2. Dimensioning of the warehouse.
3. Economic evaluation of the project.
4. Life cycle analysis of the new logistics compared to the current one.
5. Drafting of the project conclusions.

In order to design the warehouse, the minimum necessary stock corresponding to the wind farms in the East zone [2] has been obtained. To do so, it has been necessary to obtain the annual failure rate of each of the technologies as well as the repair and supply times of the components. Once the minimum stock has been obtained, the dimensions of one of the warehouses available for use as a warehouse are evaluated.

On the other hand, the economic valuation has been carried out taking into account the transport costs provided by the subcontracted companies and the annual failure rate of the components of each park. In addition, the costs associated with the transfer of the components from the Central Warehouse in As Pontes to the new warehouse and its conditioning costs have been considered.

Finally, the environmental assessment was carried out using the SimaPro life cycle analysis software, in which both the current logistics and the logistics associated with the project were modeled, to compare them and obtain the expected reduction in the carbon footprint of the project.

5. Results

5.1. Design of the new warehouse

Due to the dismantling of the Andorra thermal power plant in Teruel, the facilities that supported the said plant have become obsolete. Among them, there are several warehouses that could serve as storage for large wind components, thanks to their location, which is much closer to a significant number of wind farms within the EGPE fleet.

5.1.1. Available space

Figure 3 shows a view of the former thermal power plant and its facilities:

Figure 3 Old thermal power plant in Andorra.

In **Figure 3**, the chosen warehouse has been highlighted in red as it is the largest one. Even though the building already exists, with its corresponding electrical installation, it is necessary to assess whether the available space is sufficient and to condition it for use as a storage facility. The main warehouse has an area of 7720 m2, while the exterior yard has an area of 69660 m2.

5.1.2. New warehouse's stock

The new warehouse aims to provide support to all the parks in the East region, both the existing ones and those expected to be installed in the coming years. To assess the number of components the warehouse will accommodate, the following factors are considered:

- The number of wind turbines for each technology.
- Failure rate of the different components for each technology.
- Repair lead time.
- Supply lead time.

The failure rate is obtained from the number of component replacements for each technology in the last five years [5], considering the entire EGPE fleet to ensure a larger sample size. The results obtained are shown in ***Table 1***:

Table 1 Failure rate

Technology	**Component**					
	Gearbox	Generator	Main shaft	Transformer	Blades	Blade bearings
AE20	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
AE23	30,0%	20,0%	0,0%	0,0%	10,0%	0,0%
AE26	0,0%	20,0%	0,0%	0,0%	0,0%	0,0%
AE3X	6,5%	0,7%	0,0%	0,1%	0,0%	0,0%
AE46	3,1%	1,0%	2,9%	6,2%	0,5%	0,0%

AE61	1,4%	1,4%	1,4%	0,0%	0,0%	0,0%
AW77	0,0%	3,4%	0,0%	0,0%	0,0%	0,3%
AW132	0,0%	0,0%	0,0%	0,9%	0,0%	0,0%
BB1.3	10,0%	15,5%	5,0%	10,5%	3,5%	0,0%
ECT44	5,9%	9,4%	1,2%	0,0%	4,7%	0,0%
E-44	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
E-48	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
E-70	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
E-82	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
G114	1,9%	0,0%	0,0%	0,0%	0,0%	0,0%
G132	7,9%	0,4%	1,9%	2,6%	0,4%	0,7%
G47	3,0%	4,3%	1,7%	2,6%	7,2%	1,3%
G52	5,0%	5,6%	1,7%	1,7%	1,3%	3,8%
G58	2,8%	2,6%	1,3%	0,7%	2,0%	5,0%
G8X	1,7%	2,1%	0,2%	0,9%	0,4%	2,4%
G90	4,9%	0,0%	0,0%	0,5%	0,0%	0,0%
NM52	0,6%	7,0%	5,7%	1,6%	1,0%	0,0%
NTK37	0,0%	18,3%	0,0%	0,0%	0,0%	0,0%
NTK43	8,2%	7,8%	8,0%	16,2%	0,7%	0,0%
V42	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
V110	1,5%	0,0%	0,0%	0,0%	1,0%	0,0%
V136	1,5%	0,0%	0,0%	0,0%	1,0%	0,0%
V80/V90	3,9%	3,9%	0,7%	1,4%	0,0%	0,0%
N155	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

On the other hand, the repair and supply lead times are provided by different service and component suppliers. Taking all the above into consideration, the minimum stock is obtained, as shown in Table 2.

Table 2 Minimum stock

Technology	Component					
	Gearbox	Generator	Main shaft	Transformer	Blades	Blade bearings
AE3X	4	3	N/A	1	6	0
AE46	4	2	4	2	5	0
AE61	0	0	0	0	0	0
AW77	1	5	0	1	3	3
AW132	0	1	0	1	0	0
G52	3	2	3	3	3	15
G58	5	3	4	5	9	18
G8X	2	2	1	2	1	4
G114	1	0	0	0	0	0
G132	2	0	1	0	0	3
V8X-V9X	3	2	1	1	2	0
V110	1	0	0	0	0	0
V136	3	2	N/A	1	4	0

This minimum stock will be taken into account when evaluating the dimensions of the warehouse. It is likely that the minimum stock will change over the years due to several factors. On one hand, the older parks will undergo repowering after 30 years of operation, which involves replacing the older, lower-power machines with a smaller number of higher-power machines. Additionally, the new machines will start with a zero annual failure rate, which will increase over the years as they age. These factors will influence the stock requirements and need to be considered during the warehouse planning and management process.

5.1.3. Design

The storage area will consist of two parts: an interior and an exterior section. On one hand, the warehouse will accommodate the necessary generators, gearboxes, transformers, and blade bearings. On the other hand, an exterior yard will be conditioned to store the blades due to their large size.

Based on the minimum stock obtained and the dimensions of the components to be stored, a total of 840 m2 of usable surface area will be required, in addition to the space needed for circulation pathways. The warehouse where the large components will be housed will require overhead cranes for maneuvering, thus it should be allocated to Warehouse A. Moreover, as previously mentioned, Warehouse A has a total area of 4087 m2, indicating that it provides sufficient space for storing all the required stock. Figure 4 shows the distribution of components in the Central Warehouse of As Pontes, which will be assimilated into the layout of the new warehouse.

Figure 4 Stock distribution in Central Warehouse EGPE. [3]

On the other hand, taking into account the dimensions of the blades and the minimum stock required, the following distribution is proposed:

- 6 AE 3X blades: 6 * 1.5 * 20
- 5 AE 46 blades: 5 * 1.5 * 21
- 3 AW77 blades: 3 * 2.6 * 40
- 12 G5X blades: 12 * 1.5 * 30
- 1 G8X blade: 1 * 2.3 * 45
- 2 V8X-V9X blades: 2 * 4 * 45
- 4 V136 blades: 4 * 5.7 * 65

The space occupied by the blades according to this distribution will be 2854.2 m2. As mentioned earlier, the exterior yard has a total area of 69660 m2, providing more than enough space to accommodate the blades.

Furthermore, space will be left for truck and crane circulation pathways so they can pick up and deposit the blades. Specifically, the circulation pathways should have a minimum width of 3 meters. ***Figure 5*** shows the distribution of blades in the Central Warehouse of As Pontes, which will be the layout used in the exterior camp of the new warehouse.

Figure 5 Blade layout in Central Warehouse EGPE

5.2. Economic valuation

5.2.1. Conditioning costs

For the conditioning of the warehouse as a new storage facility for large components, several actions are required to ensure the safety of the building and electrical installation. Additionally, this construction project will generate waste that needs to be properly managed.

- Manual alarm detection
- Fire suppression systems
- Hydrant systems
- Evacuation planning
- Fencing for the exterior yard
- Construction waste management
- Electrical installation

The costs associated to these actions rises to 112.425,15€ and will be amortized in the 40 years of service life of the warehouse.

5.2.2. Operation costs

The operating costs of the warehouse will be associated with its electricity consumption and the warehouse personnel. It is estimated that the monthly electricity bill will be around 1500€, and the personnel costs will be approximately 8000€, based on the reference of the General Warehouse of EGPE in As Pontes. The warehouse personnel will be responsible for both the daily operations of the warehouse and the loading and unloading of components in the warehouse.

5.2.2. Component relocation costs

To evaluate the project, the cost associated with the transfer of components from the General Warehouse of EGPE in As Pontes to the new warehouse in Andorra must also be taken into account. This cost considers the minimum stock shown in ***Table 2*** and the distance between both warehouses, which is approximately 900 km. The transportation expenses, such as logistics, fuel, and labor costs, will be considered in assessing the overall project feasibility.

The transportation of gearboxes, generators, main shafts, transformers, and blade bearings is carried out using tautliner trucks with three axles and a loading capacity of 14 tons, as well as trailers with all-wheel-drive tractors and a loading capacity of 24 tons (EGPE, 2023). On the other hand, the transportation of Gamesa G5X and Made blades is done using extendable platforms with a length of 29 meters. For the G8X blades, the transportation uses extendable platforms ranging from 45 to 56 meters. The tractors used for transporting the blades can have 2, 3, or 4 axles and a loading capacity ranging from 25 to 90 tons. These specific transportation arrangements are chosen to accommodate the dimensions and weight of the blades, ensuring safe and efficient delivery to the new warehouse in Andorra.

Considering the dimensions of the components to be transported and the specifications of the transportation means (DSV Spain, s.f.), it is estimated that a 3-axle truck could transport the components listed in ***Table 3***.

Table 3 3-axle truck capacity according to technology and component

Technology	Component				
	Gearbox	Generator	Main shaft	Transformer	Blades
< 1,5 MW	4	4	4	4	6
> 1,5 MW	1	3	3	3	6

On the other hand, the transportation of blades is carried out in groups of three for technologies with less than 1.5 MW and individually for the rest. Therefore, it is concluded that 39 3-axle trucks and 19 extendable platforms will be required, resulting in the following costs associated with the transfer of the components:

$$\text{Relocation costs} = (39 * 3\ €/km + 19 * 6\ €/km) * 900\ km = 207900\ € \quad (1)$$

5.2.3. Transportation costs

As the economic assessment of the project is done comparatively, only the logistics associated with the large components of the East region's parks will be considered. The transportation cost is obtained from the average prices provided by the contracting companies.

Below, ***Table 4*** shows the distances from each warehouse to the parks in the East region: 223

Table 4 Comparison of distances. [10] 224

Wind farm	Distance As Pontes (km)	Distance Andorra (km)	Difference(km)
Acampo	790	83	707
Ágreda	647	228	419
Aguilón	814	89	725
Almarén	697	162	535
Casillas I	937	189	748
Casillas II	948	199	749
Caldereros	797	143	654
Cantiruela	499	417	82
Cogollos II	475	428	47
El Puerto - Trinidad	886	417	469
Escucha + Sant Just	888	65	823
Les Forques	978	215	763
Los Llanos	472	425	47
Montargull	994	233	761
Aragón	781	141	640
La Muela II	778	131	647
Las Pardas	495	414	81
Peña II	790	181	609
Picazo	706	190	516
Saso Plano	821	174	647
Sierra Del Cortado I	627	234	393
Sierra Del Cortado II	632	227	405
Ampliación Los Llanos	552	388	164
El Campo	713	175	538
La Estanca	705	171	534
Loma Gorda	807	70	737
Santo Domingo De Luna	758	155	603
Allueva	767	87	680
Sierra Pelarda	766	87	679
Muniesa	827	56	771
Farlán	828	58	770
San Pedro De Alacón	834	47	787
Sierra Costera I	867	86	781
Campoliva I	773	103	670
Campoliva II	770	117	653
Primoral	773	103	670
Cañaseca	813	64	749
San Francisco De Borja	713	177	536
Dehesa De Mallén	710	176	534
Los Gigantes	812	66	746
Tico	838	76	762

Considering all the previous data, the annual failure rate (AFR) obtained in ***Table 1***, and the transportation prices, the transportation cost is calculated using the following expression:

$$\text{Transportation costs} = \text{Number of wind turbines}*\text{AFR}*\text{Price}*\text{Distance}*2 \quad (2)$$

The result of the expression corresponds to the annual transportation cost associated with a component in a specific park. Therefore, the total cost will be obtained by summing up this expression for all the parks and their corresponding components. Additionally, the distance is multiplied by two to account for the round trip of the component, as the component removed from the machine will be transported back to the warehouse.

5.2.4. Economic results

The project is economically evaluated for the 40-year useful life of the warehouse, considering the following assumptions:

- If the previous year's failure rate is lower than 5%, it increases by 20% every 5 years.
- If the previous year's failure rate is higher than 5%, it increases by 10% every 5 years.
- The life expectancy of the parks is estimated to be 30 years. From year 31, the parks are repowered, and the failure rate is reset to 0, which will increase according to the above assumptions.
- For components with an initial failure rate of 0, it is assumed to be 1% starting from the fifth year.
- The transportation costs are adjusted annually assuming a 5% Consumer Price Index (CPI), a conservative assumption based on data from previous years [8].
- The operating costs have an annual increase of 2.5%.

Table 5 Economic results

Year	Transportation saving	Operation costs	Warehouse amortization	Relocation costs	Total
1	127.444,94 €	114.000,00 €	2.810,63 €	207.900,00 €	- 197.265,69 €
2	133.817,34 €	116.850,00 €	2.810,63 €	- €	14.156,71 €
3	140.508,50 €	119.771,25 €	2.810,63 €	- €	17.926,62 €
4	147.534,37 €	122.765,53 €	2.810,63 €	- €	21.958,21 €
5	154.911,69 €	125.834,67 €	2.810,63 €	- €	26.266,39 €
6	162.658,01 €	128.980,54 €	2.810,63 €	- €	30.866,85 €
7	170.791,81 €	132.205,05 €	2.810,63 €	- €	35.776,13 €
8	179.332,44 €	135.510,18 €	2.810,63 €	- €	41.011,63 €
9	188.300,25 €	138.897,93 €	2.810,63 €	- €	46.591,69 €
10	197.716,61 €	142.370,38 €	2.810,63 €	- €	52.535,60 €
11	207.603,92 €	145.929,64 €	2.810,63 €	- €	58.863,66 €
12	217.985,76 €	149.577,88 €	2.810,63 €	- €	65.597,25 €
13	228.886,83 €	153.317,33 €	2.810,63 €	- €	72.758,88 €
14	240.333,11 €	157.150,26 €	2.810,63 €	- €	80.372,22 €
15	252.351,85 €	161.079,02 €	2.810,63 €	- €	88.462,20 €
16	264.971,67 €	165.105,99 €	2.810,63 €	- €	97.055,05 €
17	278.222,64 €	169.233,64 €	2.810,63 €	- €	106.178,37 €
18	292.136,30 €	173.464,48 €	2.810,63 €	- €	115.861,19 €
19	306.745,79 €	177.801,09 €	2.810,63 €	- €	126.134,07 €
20	322.085,91 €	182.246,12 €	2.810,63 €	- €	137.029,16 €
21	338.193,18 €	186.802,27 €	2.810,63 €	- €	148.580,28 €
22	355.105,97 €	191.472,33 €	2.810,63 €	- €	160.823,00 €
23	372.864,54 €	196.259,14 €	2.810,63 €	- €	173.794,77 €
24	391.511,19 €	201.165,62 €	2.810,63 €	- €	187.534,94 €
25	411.090,32 €	206.194,76 €	2.810,63 €	- €	202.084,93 €

26	431.648,56 €	211.349,63 €	2.810,63 €	- €	217.488,30 €
27	453.234,85 €	216.633,37 €	2.810,63 €	- €	233.790,86 €
28	475.900,61 €	222.049,20 €	2.810,63 €	- €	251.040,78 €
29	499.699,81 €	227.600,43 €	2.810,63 €	- €	269.288,75 €
30	524.689,12 €	233.290,44 €	2.810,63 €	- €	288.588,05 €
31	550.928,04 €	239.122,70 €	2.810,63 €	- €	308.994,71 €
32	578.479,06 €	245.100,77 €	2.810,63 €	- €	330.567,65 €
33	607.407,77 €	251.228,29 €	2.810,63 €	- €	353.368,85 €
34	637.783,07 €	257.509,00 €	2.810,63 €	- €	377.463,44 €
35	669.677,28 €	263.946,72 €	2.810,63 €	- €	402.919,93 €
36	703.166,36 €	270.545,39 €	2.810,63 €	- €	429.810,34 €
37	738.330,03 €	277.309,03 €	2.810,63 €	- €	458.210,38 €
38	775.252,04 €	284.241,75 €	2.810,63 €	- €	488.199,66 €
39	814.020,30 €	291.347,80 €	2.810,63 €	- €	519.861,87 €
40	854.727,12 €	298.631,49 €	2.810,63 €	- €	553.285,00 €

Thanks to the project, more than 7 million euros will be saved over the next 40 years. It is worth mentioning that this economic evaluation assumes the same number of machines for the next 40 years, although this may not be accurate as the repowering of parks may lead to a decrease in the number of machines. However, new machines from the projects mentioned in the Justification section will also be added. Since information on the exact number of machines to be removed from old parks and those to be incorporated into new parks is not currently available, a constant machine scenario is considered to evaluate the project conservatively.

On the other hand, the loss of €197,256.69 in the first year will be recovered in the ninth year, with a net saving of €37,288.54 that continues to grow in the following years.

The economic evaluation of the project has been carried out for the first 40 years since the project's inception, which coincides with the useful life of the warehouse. However, it is expected that the warehouse can be utilized for many more years, and once the warehouse is fully amortized, the only costs would be related to the operation and maintenance of the warehouse, resulting in increased project profitability.

5.3. Environmental valuation

The inventory of both processes will be similar. For the current process, only the impact associated with component transportation will be included. However, for the future scenario, the inventory will consider the conditioning of the warehouse, the transportation of components from the As Pontes warehouse to the new warehouse, and finally, the transportation of components resulting from major overhauls. These factors will be considered to assess the overall environmental impact of the project.

5.3.1. Inventory analysis

Relocation phase

In this phase, the transportation associated with the transfer of components currently located in the Central Warehouse of As Pontes to the new warehouse will be included. The current stock in the Central Warehouse that will be moved to the new warehouse corresponds to the minimum stock shown in the previous Table 2.

The transportation methods used will be the same as those employed for major overhauls, as detailed in section 6.2 "Component Transportation Costs." To model these transports in SimaPro, the following transports from the database are selected:

- For the transportation of gearboxes, generators, main shafts, transformers, and blade bearings: Transport, freight, lorry 16-32 metric ton, EURO6 {RER} | transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U
- For the transportation of blades: Transport, freight, lorry >32 metric ton, EURO6 {RER} | transport, freight, lorry >32 metric ton, EURO6 | Cut-off, U

Transportation phase

To evaluate the transportation process, the number of annual major overhauls corresponding to each park is taken into account. On the other hand, as the functional unit for the life cycle assessment is the mass (kg) transported annually, the inputs for this phase will be obtained using the following expression:

$$\text{Mass} = \text{Number of wind turbines}*\text{AFR}*\text{Component mass} \quad (3)$$

This expression will be obtained for each of the components mentioned earlier. Additionally, in SimaPro, transports are input in tonne-kilometers (tkm), so it will be necessary to multiply the mass of each component by the corresponding distance from the warehouse to the park. This conversion is done to calculate the total tonne-kilometers associated with each component's transportation, considering the distance traveled between the warehouse and the parks.

Operation phase

Regarding the operation of the warehouse throughout its useful life, the energy consumption of the facility is considered. It is assumed that the energy consumption comes from the Spanish energy mix. Taking the energy consumption of the Central Warehouse in As Pontes as a reference, which is 8200 kWh/month, a monthly consumption of 4555 kWh is assumed, resulting in an annual consumption of 54660 kWh. This estimation is used to evaluate the energy consumption of the new warehouse during its operational life.

5.3.2. Life cycle analysis

The methods used to calculate the environmental impacts are as follows:

1. CML Baseline: This method evaluates the impact of a process in different categories, including abiotic depletion, abiotic depletion (fossil fuels), global warming potential, ozone depletion potential, human toxicity, freshwater ecotoxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity, photochemical oxidation, acidification, and eutrophication.

2. Cumulative Energy Demand: This method assesses the energy consumption of a process, analyzing different types of primary energy. It provides insights into the total energy usage and helps in understanding the energy-related environmental impacts of the project.

Figure 6 *CML Baseline results****Figure 6*** shows that future logistics, thanks to the new warehouse, would decrease most of the environmental impacts analyzed.

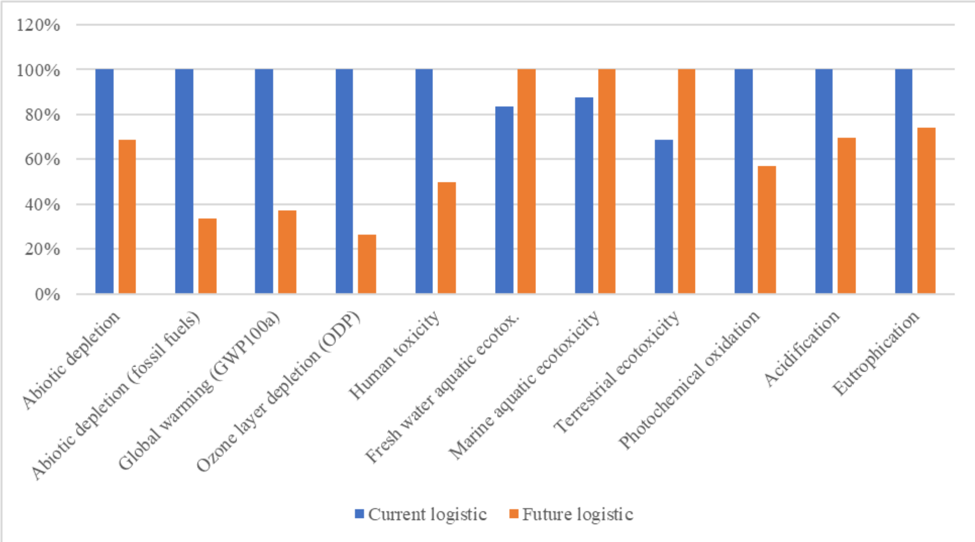

Figure 6 CML Baseline results

On the other hand, ***Figure 7Figure 7*** shows that, thanks to the new warehouse, the logistics related to major correctives would consume much less energy. In particular, the demand of energy from fossil fuel, which is the most polluting in terms of carbon footprint, would decrease more than 60%.

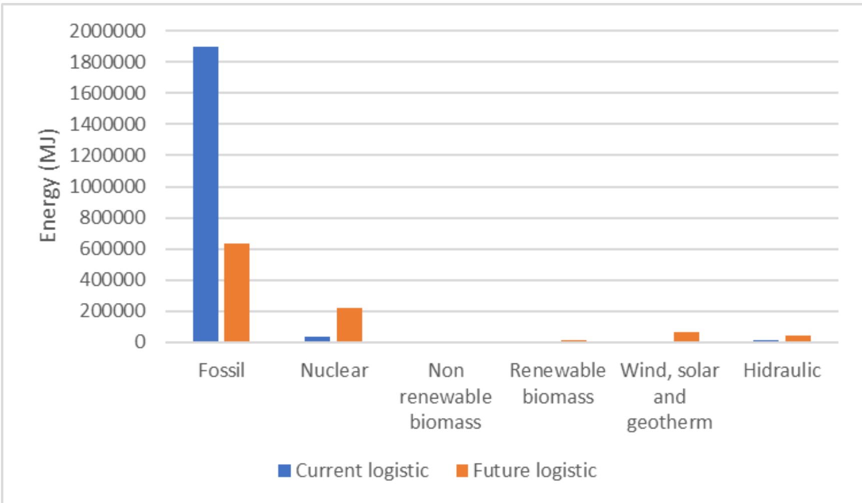

Figure 7 Cumulative Energy Demand results

6. Discussion

In this project, three main results have been obtained: firstly, the feasibility of converting one of the warehouses of the former thermal power plant in Teruel into a new warehouse for wind turbine components has been confirmed; secondly, the economic profitability of the project due to transportation savings; and thirdly, the reduction in carbon footprint and other environmental impacts.

<u>Results of the economic assessment:</u>

Regarding the economic evaluation, a more favorable result than expected has been obtained, with a profit of over 7 million euros throughout the project. This is not an exact calculation but an estimation, considering various assumptions that could alter the actual result. However, the study has been conducted conservatively to approach reality as closely as possible. On the other hand, the project requires an initial investment of €207,900 for component transportation and €112,425.25 for warehouse conditioning. The warehouse conditioning is amortized over its useful life, while the component transportation cost is applied in the first year of the project. Thus, the initial investment of €207,900 is recovered from year 9 onwards. The economic evaluation has been carried out over 40 years, during which the warehouse conditioning is amortized. After year 41, almost all the savings would become profit, minus the operation and maintenance costs of the warehouse.

The positive result of the economic evaluation is attributed, among other factors, to the assumption of a 5% increase in transportation costs based on the recent IPC increase in the sector (Expansión, s.f.), taking into account the volatility of transportation costs. Furthermore, the hypothesis of an increasing failure rate of components over their lifespan leads to more major overhauls, resulting in greater transportation savings through the project.

<u>Results of the environmental assessment:</u>

Regarding the environmental assessment, current logistics dominates the impact in all evaluated aspects, except for ecotoxicity, which is minimal since it is derived from indirect impacts of the Spanish electricity mix. To confirm this analysis, the energy demand of both processes is obtained, and it is observed that the demand of current logistics is much higher than that of the proposed project, with the impact on fossil fuel demand being particularly notable.

Regarding the carbon footprint, which is the main aspect to study, it is measured in CO2 equivalent when evaluating the impact on global warming. The comparative impact of current logistics versus logistics with the new warehouse is presented in Graph 8.1.

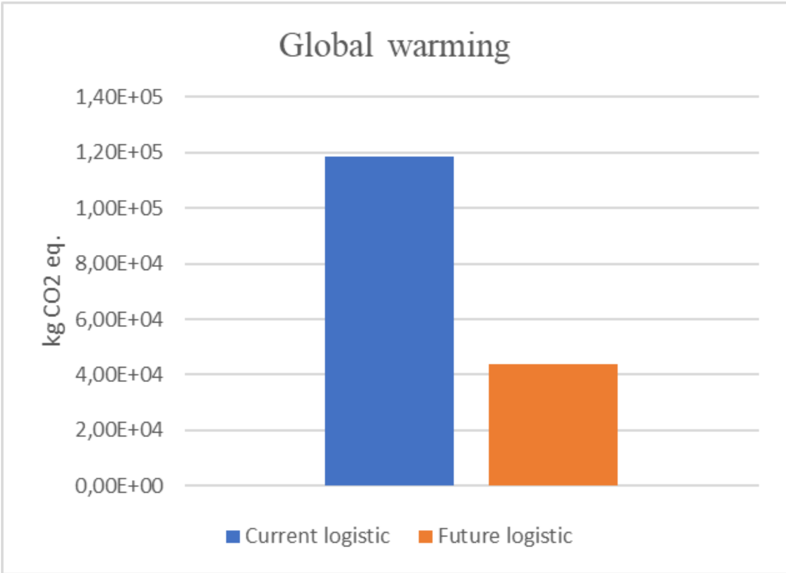

Figure 8 Comparison of impact on global warming.

7. Conclusions

The use of the existing building at the former Andorra thermal power plant will reduce both transportation costs and the associated carbon footprint.

This is a long-term profitable project, whose initial investment will be recovered after the ninth year. In addition, the reduction in the distance between the eastern wind farms and the storage facility will significantly reduce the carbon footprint associated with large corrective actions.

In view of the above and considering the assumptions made, it is concluded that the project for the new wind component storage facility in Andorra is economically viable and profitable in environmental terms.

In addition, Enel Green Power España expects to grow a lot in the coming years in terms of wind technology, so this project allows to anticipate the needs of future wind farms that will be incorporated into the fleet. On the one hand, the transfer of components to the new warehouse frees up the Central Warehouse in As Pontes and thus leaves more space for the components of the wind farms that will be inaugurated in the coming years in the area, and on the other hand, the new warehouse will be used for the numerous wind farms that will be inaugurated in the eastern area.

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