MEC-E1070 Selection of Engineering Materials

Task 5: Materials and the Environment + Processes

Task 5.1.1:

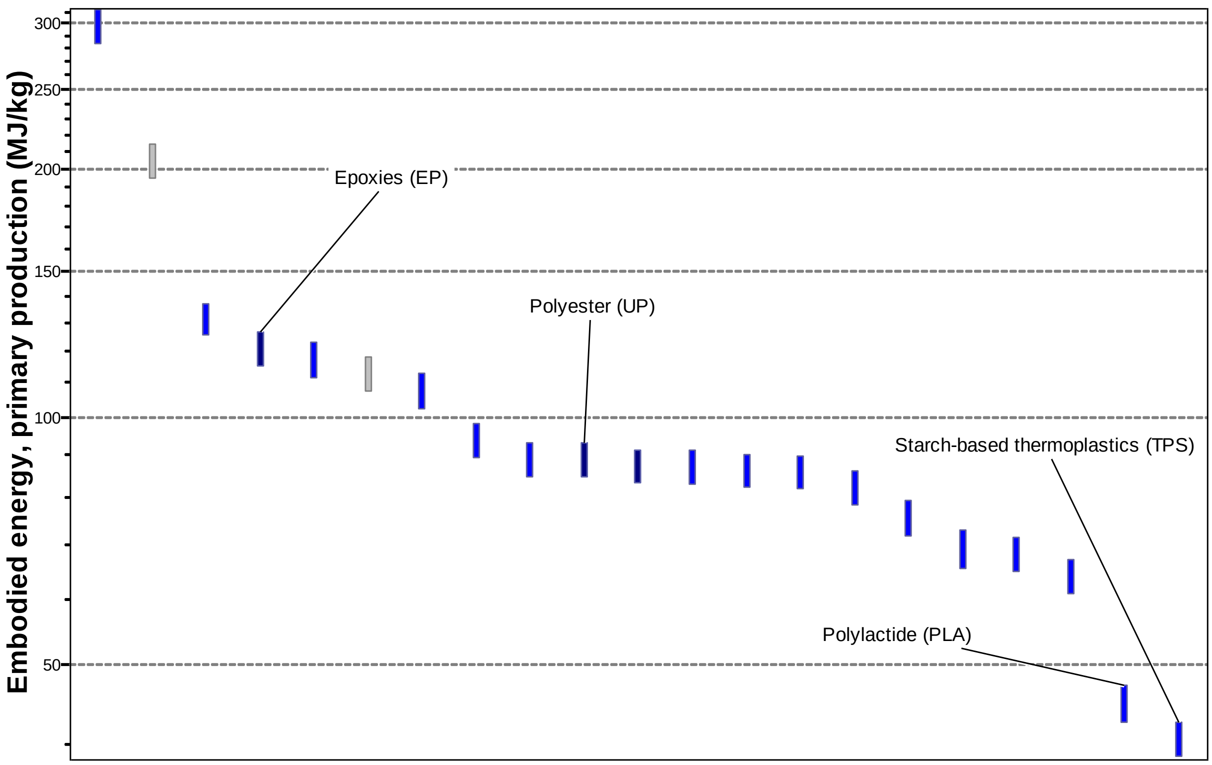

Figure 1

In task 5.1.1 it was asked to Estimate the amount of energy in different polymers and Which polymer embodies the least energy during its manufacture, when a Young's modulus value of at least 0.8 GPa is required. In figure 1, it has been shown that some of the polymer material has been filtered out when minimum Young`s Modulus of 0.8 GPa was set. The least amount of energy generated by the material during the production is Starch-based thermoplastics (TPS) where the primary production energy is between 38.6 MJ/Kg to 42.6 MJ/Kg and an average of 40.6 MJ/Kg. It was done through Grant Edupack level 2, Polymer Material.

Task 5.1.2:

In this it was asked to compare different material regard to beam strength (in bending) versus CO2 emissions and to identify which material possesses the smallest carbon footprint compared to strength. In figure 2, different material has been compared through drawing a map using granta Edupack level 2. A slope of 1.5 has been used to choose the best material is respect to CO_2 emission. The value of the slope has been taken based on the following equation:

$$M_3 = \frac{\sigma_f^{2/3}}{Hp.\rho}$$

It shows that the CORK provided the lowest carbon footprint with an emission between 7.65 to 11.6 with an average emission of 9.41.

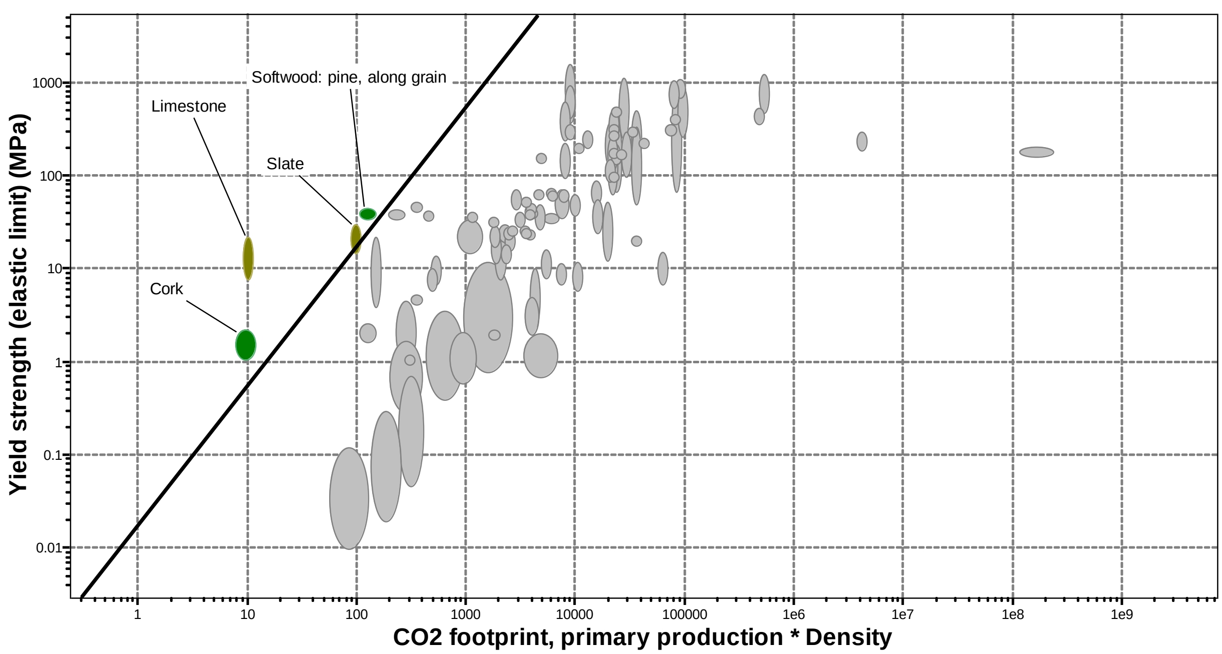

Figure 2

In the next part of this sub task, it was asked to draw up this map for beam strength versus CO2 emissions when recycled material is used. In figure 3, the non-recycled material has been filtered out and the material which can be recycled has been shown in the map. Compared to figure 2 map, in figure 3 map the concrete provided the lowest carbon footprint, but the yield strength is very low. Whereas the Low Alloy steel provides the highest Yield Strength, but low carbon footprint compared to most other materials.

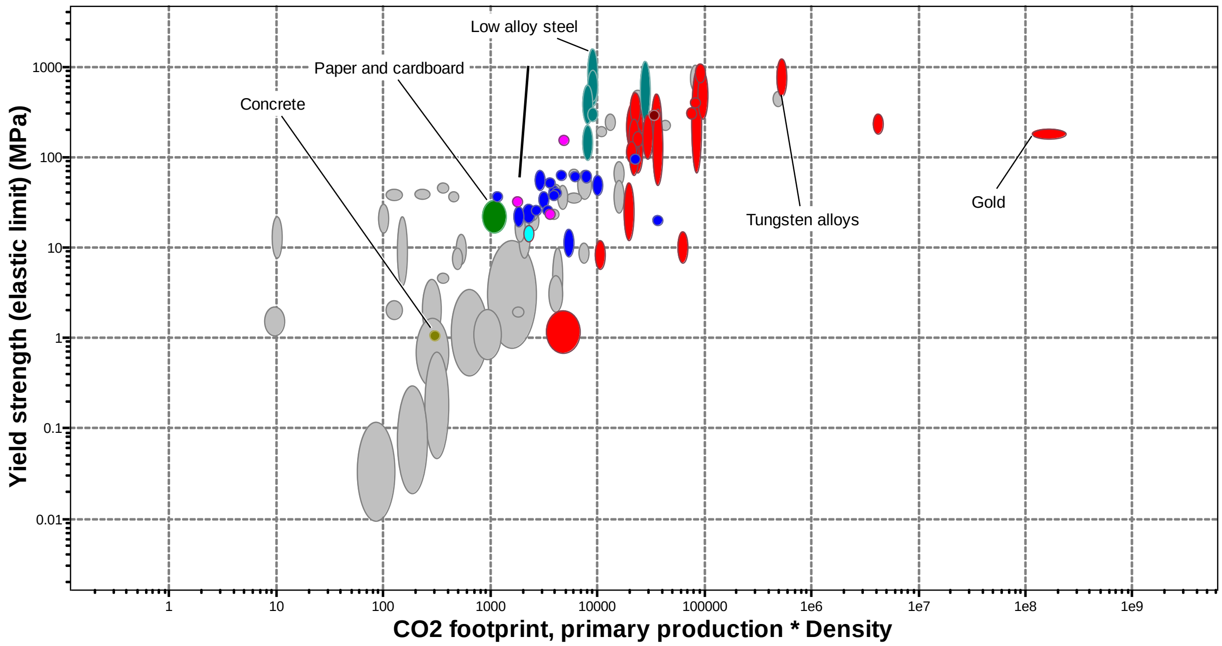

Figure 3

Task 5.1.3:

In this task it was asked to measure the energy consumption and carbon footprint during the transportation of wind turbine blade made of 3 different material of different masses.

1. **Glass-reinforced plastic (GRP)**

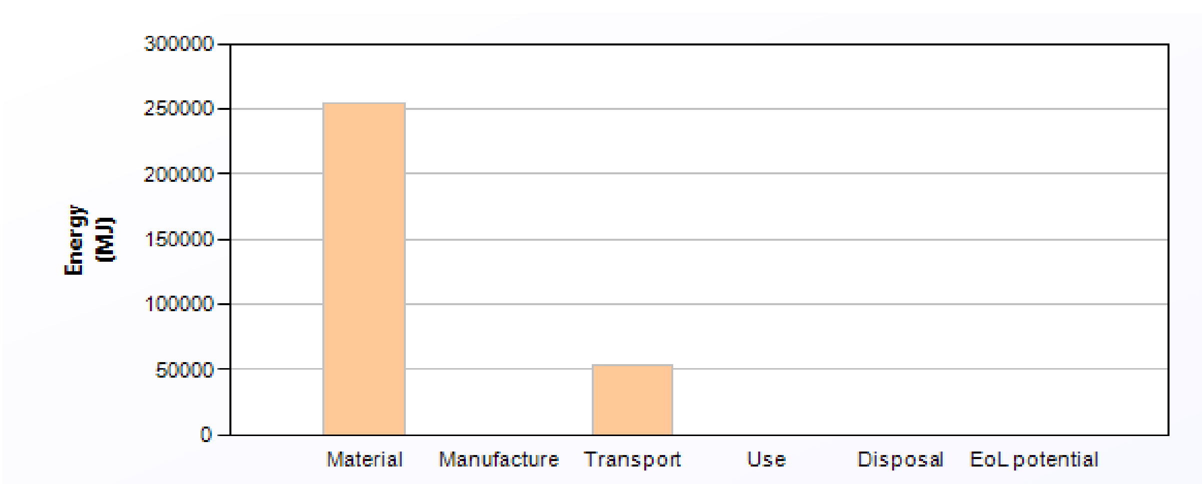

Figure 4

Table 1

Stage name	Transport type	Distance (km)	Energy (MJ)	%
truck	Truck 3.5-7.5t, EURO 3	2,6e+03	5,4e+04	100,0
Total		**2,6e+03**	**5,4e+04**	**100**

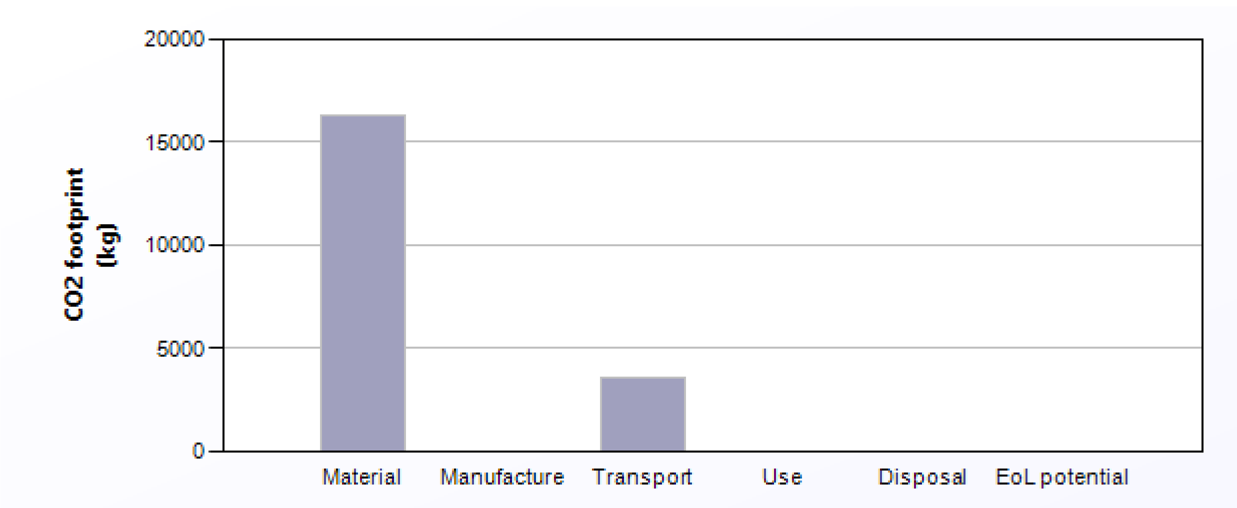

Figure 5

Table 2

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
truck	Truck 3.5-7.5t, EURO 3	2,6e+03	3,6e+03	100,0
Total		**2,6e+03**	**3,6e+03**	**100**

Component	Mass (kg)	CO2 footprint (kg)	%
Wind turbine blade	2,4e+03	3,6e+03	100,0
Total	**2,4e+03**	**3,6e+03**	**100**

In figure 4 and 5 it has been shown that the energy consumption and carbon footprint amount to transport a wind turbine blade made of GRP of mass 2400 kg with a truck of 3.5-7.5 ton capacity truck. In table 1 and 2 the value energy consumption and carbon footprint during the transportation has been specified and it was found that the energy consumption was 54000 MJ and carbon footprint was 3600 Kg.

2. **Carbon-fiber-reinforced polymers (CFRP)**

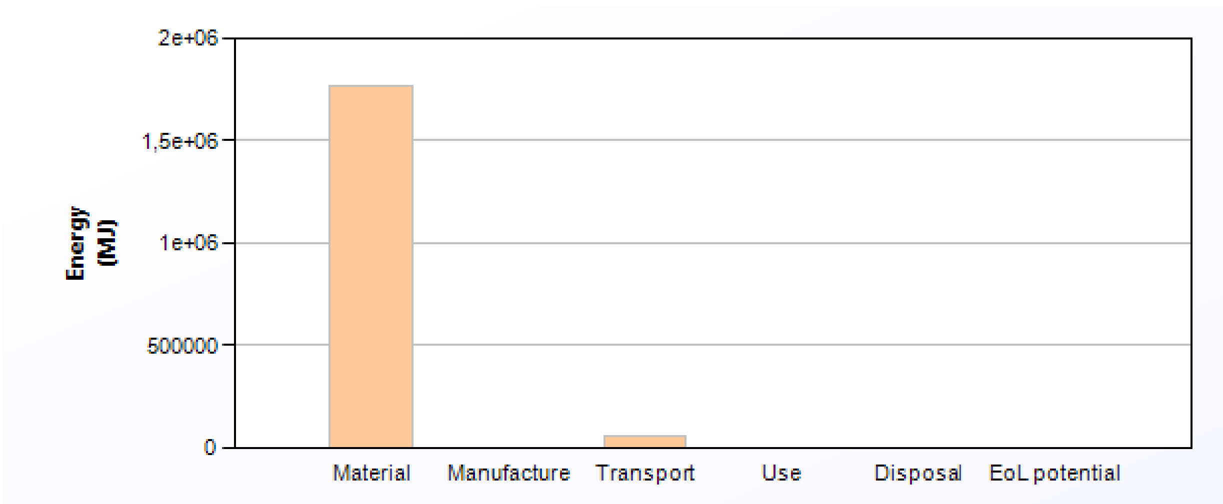

Figure 6

Table 3

Stage name	**Transport type**	**Distance (km)**	**Energy (MJ)**	**%**
truck	Truck 3.5-7.5t, EURO 3	2600,00	54587,52	100,0
Total		**2600,00**	**54587,52**	**100**
Breakdown by components				
Component	**Mass (kg)**	**Energy (MJ)**	**%**	
Wind turbine blade	2430,00	54587,52	100,0	
Total	**2430,00**	**54587,52**	**100**	

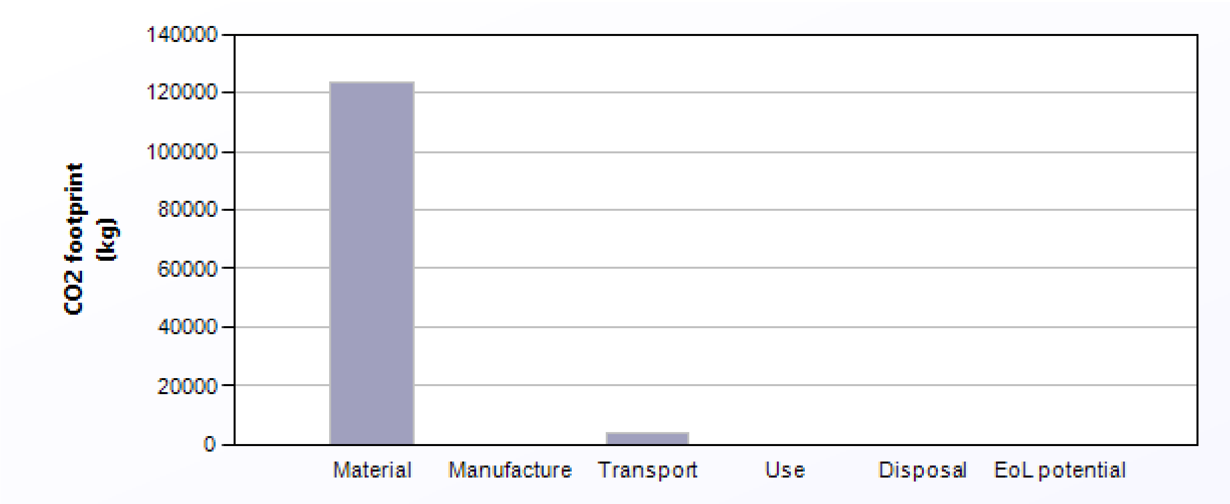

Figure 7

Table 4

Breakdown by transport stage				
Stage name	**Transport type**	**Distance (km)**	**CO2 footprint (kg)**	**%**
truck	Truck 3.5-7.5t, EURO 3	2600,00	3639,17	100,0
Total		**2600,00**	**3639,17**	**100**

Breakdown by components			
Component	**Mass (kg)**	**CO2 footprint (kg)**	**%**
Wind turbine blade	2430,00	3639,17	100,0
Total	**2430,00**	**3639,17**	**100**

In figure 6 and 7 it has been shown that the energy consumption and carbon footprint amount to transport a wind turbine blade made of CFRP of mass 2430 kg with a truck of 3.5-7.5 ton capacity truck. In table 3 and 4 the value energy consumption and carbon footprint during the transportation has been specified and it was found that the energy consumption was 54587,52 MJ and carbon footprint was 3639,17 Kg.

3. **Aluminum**

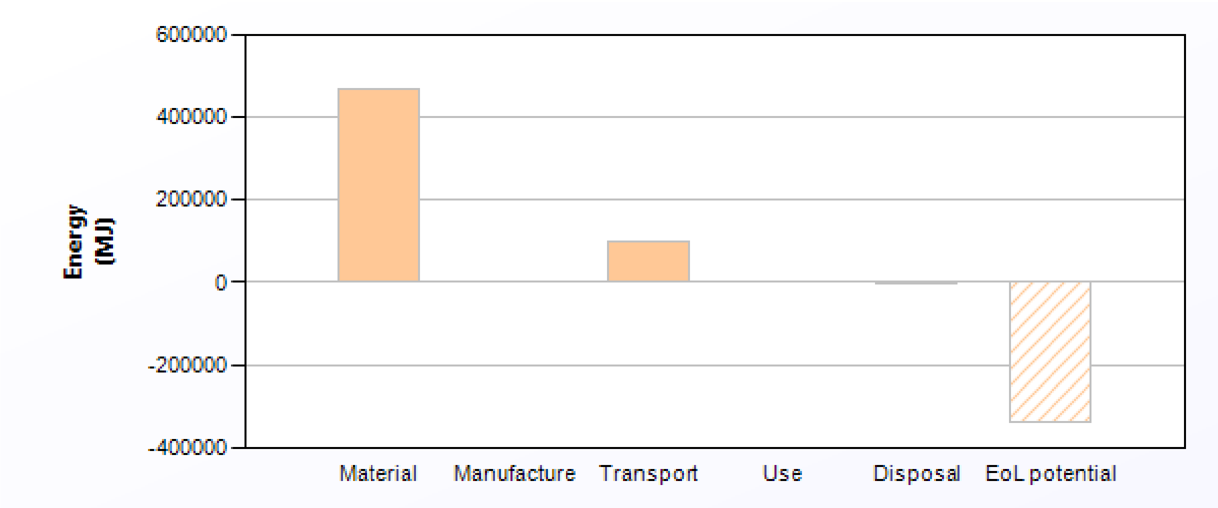

Figure 8

Table 5

Breakdown by transport stage

Stage name	Transport type	Distance (km)	Energy (MJ)	%
truck	Truck 3.5-7.5t, EURO 3	2,6e+03	9,7e+04	100,0
Total		**2,6e+03**	**9,7e+04**	**100**

Breakdown by components

Component	Mass (kg)	Energy (MJ)	%
Wind turbine blade	4,3e+03	9,7e+04	100,0
Total	**4,3e+03**	**9,7e+04**	**100**

Table 6

Breakdown by transport stage

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
truck	Truck 3.5-7.5t, EURO 3	2,6e+03	6,5e+03	100,0
Total		**2,6e+03**	**6,5e+03**	**100**

Breakdown by components

Component	Mass (kg)	CO2 footprint (kg)	%
Wind turbine blade	4,3e+03	6,5e+03	100,0
Total	**4,3e+03**	**6,5e+03**	**100**

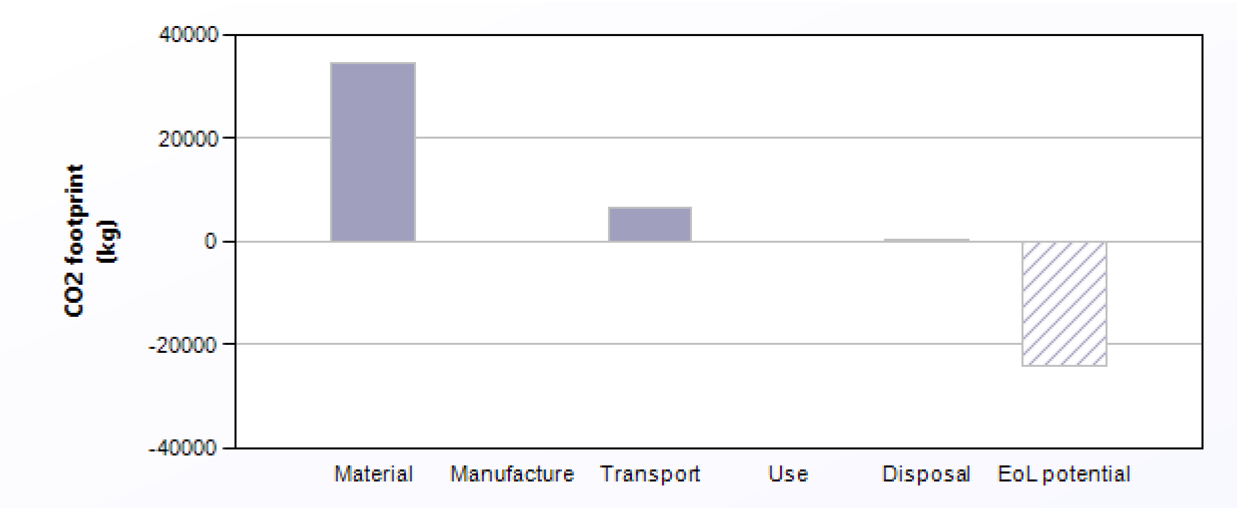

Figure 9

In figure 8 and 9 it has been shown that the energy consumption and carbon footprint amount to transport a wind turbine blade made of Aluminium of mass 4320 kg with a truck of 3.5-7.5 ton capacity truck. In table 5 and 6 the value energy consumption and carbon footprint during the transportation has been specified and it was found that the energy consumption was about 97000 MJ and carbon footprint was 6500 Kg.

Task 5.1.4

Table 7

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	2,54e+05	74,9	1,63e+04	72,8
Manufacture	3,07e+04	9,0	2,46e+03	11,0
Transport	5,39e+04	15,9	3,59e+03	16,0
Use	0	0,0	0	0,0
Disposal	480	0,1	33,6	0,1
Total (for first life)	**3,39e+05**	**100**	**2,24e+04**	**100**
End of life potential	0		0	

Table 7 shows the overall environmental impact of GRP wind turbine blade. Here, the resin transfer molding has been selected as the process of manufacturing. It can be seen from the table 7 that the overall energy consumption is 339000 MJ and Carbon footprint amount is about 22400.

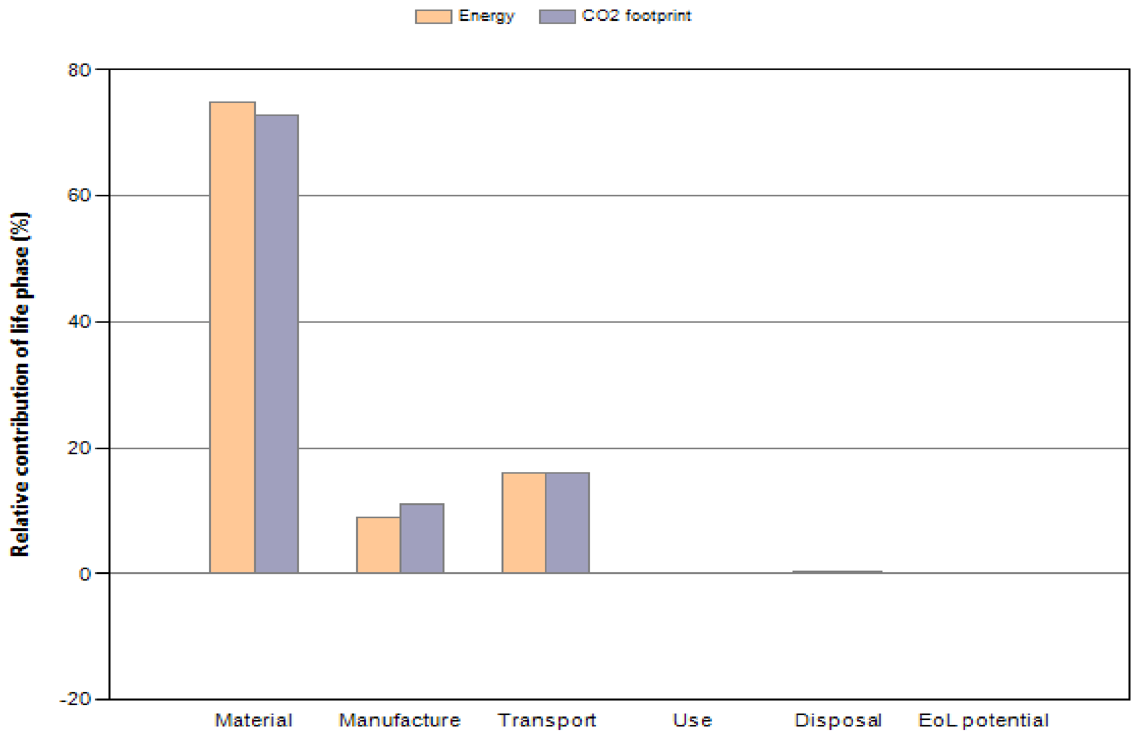

Figure 10

Figure 10 shows the comparative values of energy consumption and carbon emissions during manufacturing process, transport and the material itself. Since the after life will be landfill there is a minimal amount of energy consumption and carbon footprint during disposal.

Since polymer can not be recycled except the unsaturated polymer, so CFRP and GRP cannot be recycled. Aluminum can be recycled. Here aluminum is used, and the wind turbine blade of aluminum is made by extrusion method.

Table 8

Phase	**Energy (MJ)**	**Energy (%)**	**CO2 footprint (kg)**	**CO2 footprint (%)**
Material	4,67e+05	72,0	3,46e+04	73,1
Manufacture	8,13e+04	12,5	6,08e+03	12,8
Transport	9,7e+04	15,0	6,47e+03	13,7
Use	0	0,0	0	0,0
Disposal	3,02e+03	0,5	212	0,4
Total (for first life)	**6,48e+05**	**100**	**4,74e+04**	**100**
End of life potential	-3,36e+05		-2,43e+04	

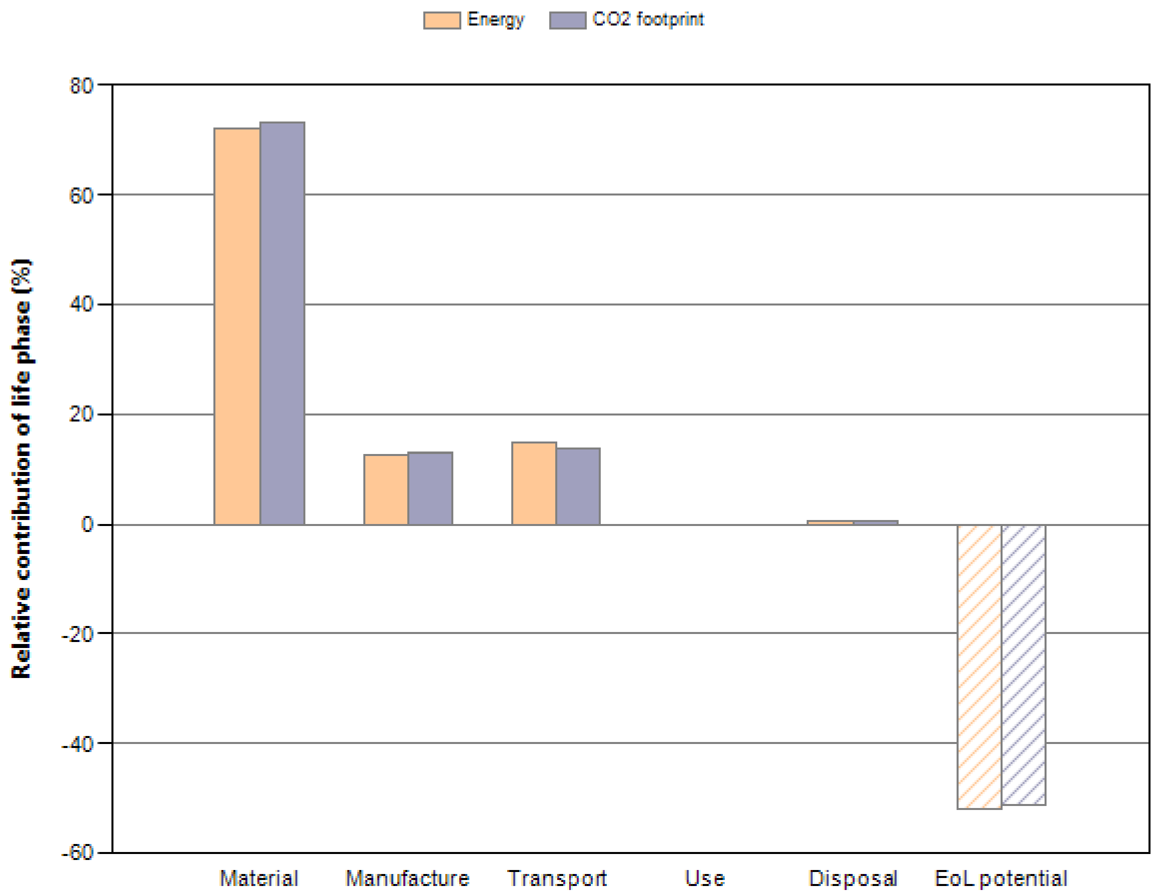

Figure 11

In table 8 the amount of energy consumption and carbon footprint of the material and during the manufacturing, disposal and transport has been shown. It also says since it will be recycle after the end of life so the potential environmental savings of EOL reduces the overall environmental impact by 50 percent. Figure 11 shows the environmental impact and savings of the aluminium wind turbine blade.

In figure 12, the comparison of overall energy consumption and carbon footprint of aluminium and GRP has been shown. It can be concluded that since the aluminium can be recycled, despite of having higher energy consumption and carbon footprint compared to GRP, it provides better environmental impact due to recycle. Due to recycle the overall environmental impact reduces and shows better result compared to GRP.

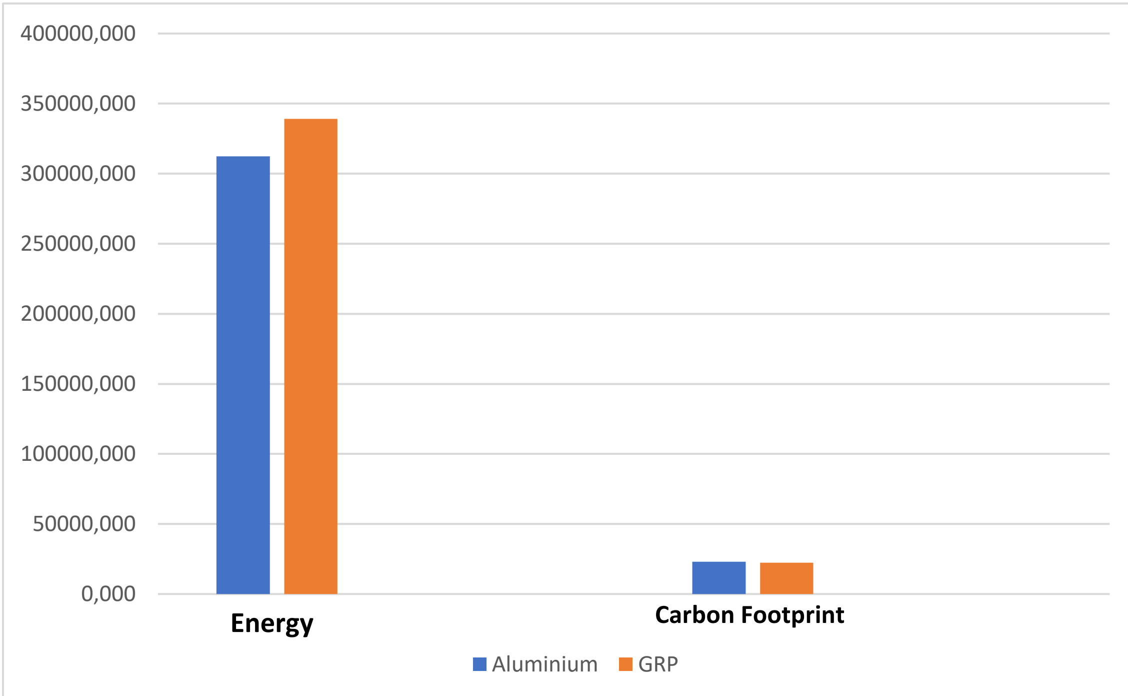

Figure 12

Task 5.2.1

The material group chosen in task 0.1 is Composite. Now in process universe of composite group, the available information in level 2 and level 3 are discussed in this sub task.

Level 2

In level 2 of composite group there are two types of composite material available. One is metal composite and another one is polymer composite. The three-example material from these two types of composite material and available information are given below:

All the three materials have three kinds of information in material universe link. Joining, Shaping and Surface Treatment. The sub sector of joining, shaping and Surface Treatment of these three materials have been shown below.

- **Aluminium/ Silicon Carbide**

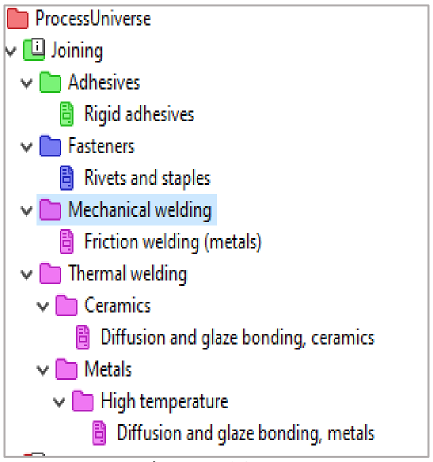

Figure 13

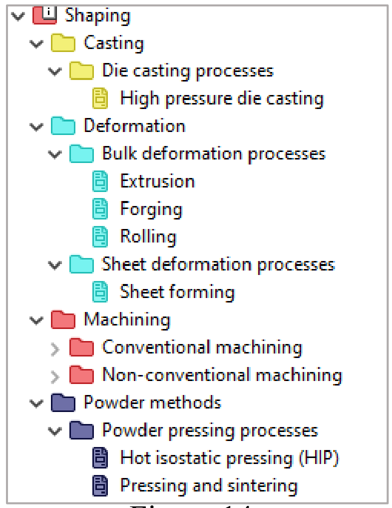

Figure 14

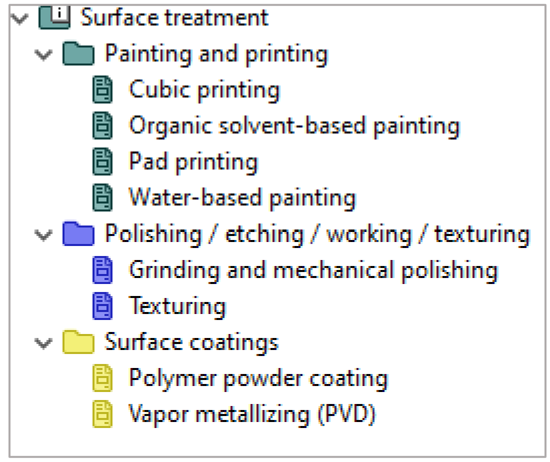

Figure 15

Figure 13 shows all the joining process of Aluminium/ Silicon carbide. Figure 14 shows all the shaping process and in figure 15, the surface treatment methods have been shown.

- **CFRP**

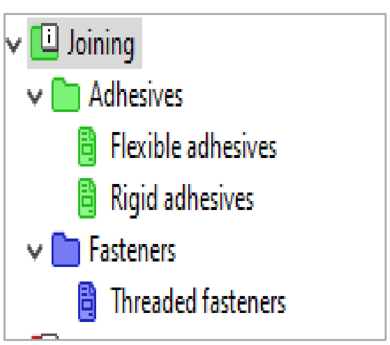

Figure 16

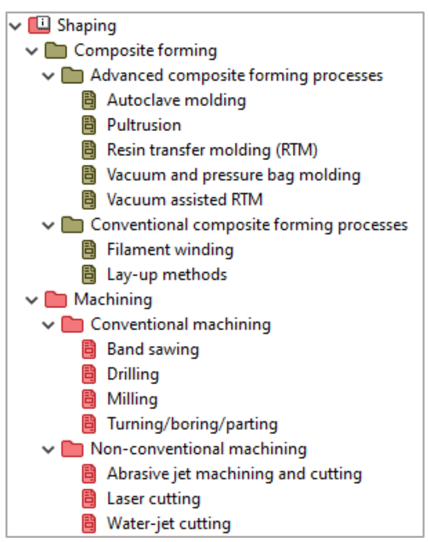

Figure 17

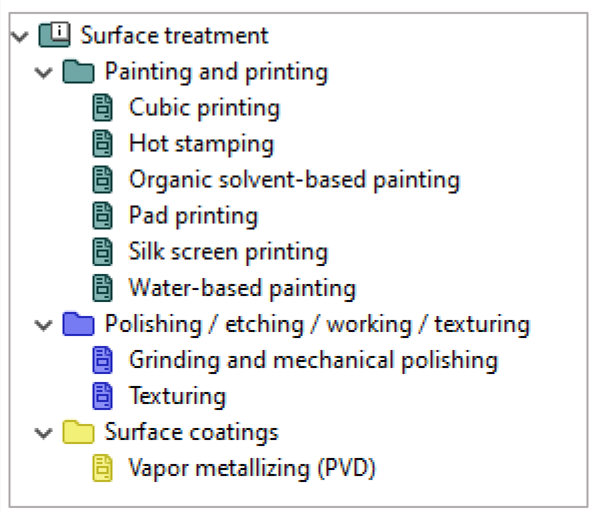

Figure 18

Figure 16 shows all the joining process of CFRP. Figure 17 shows all the shaping process and in figure 18, the surface treatment methods have been shown.

- **DMC**

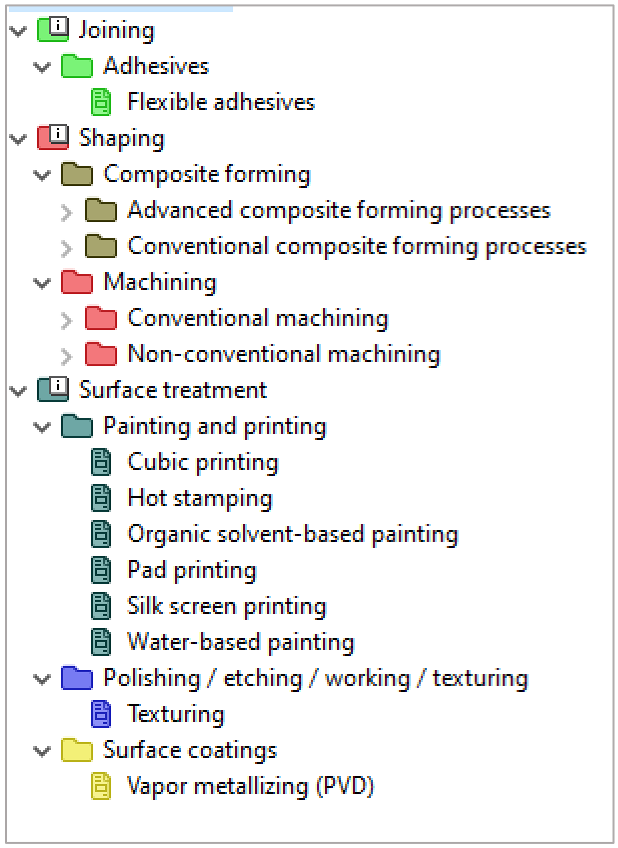

Figure 19

Figure 19 shows all the joining, shaping process and surface treatment of DMC in level 2.

Level 3

In level 3, the material family is much more extended. So similar material with level 2 materials has been discussed here.

- **Silicon Carbide -Al-47%SiC(f)**

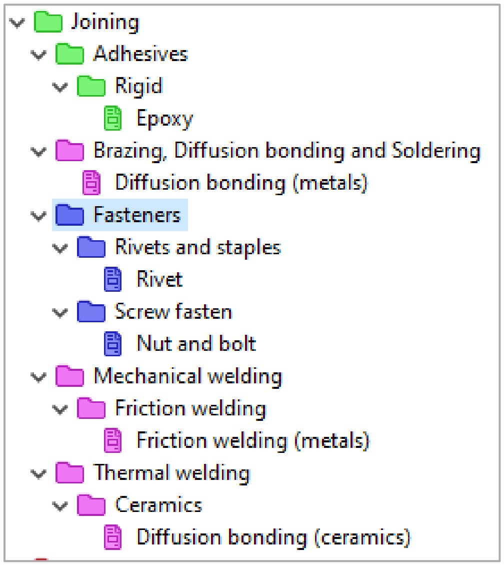

Figure 20

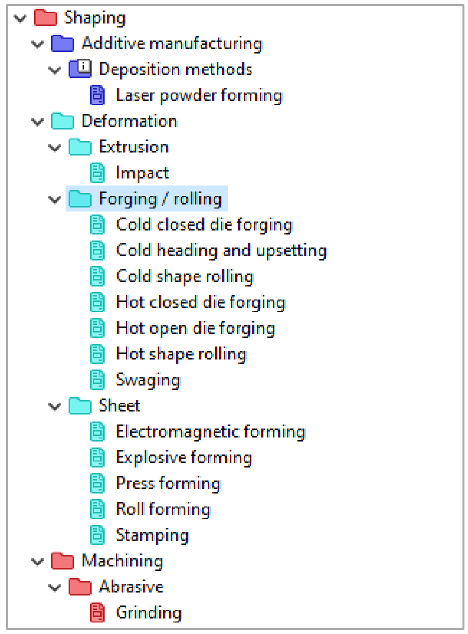

Figure 21

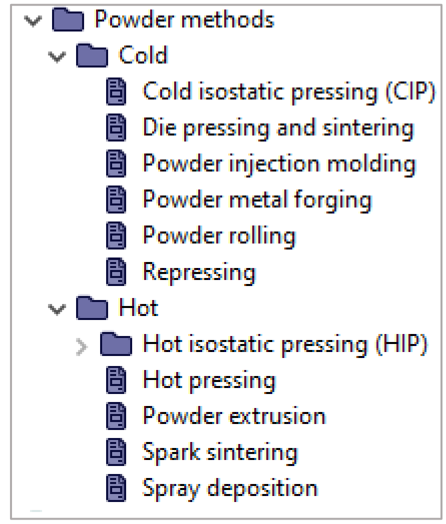

Figure 22

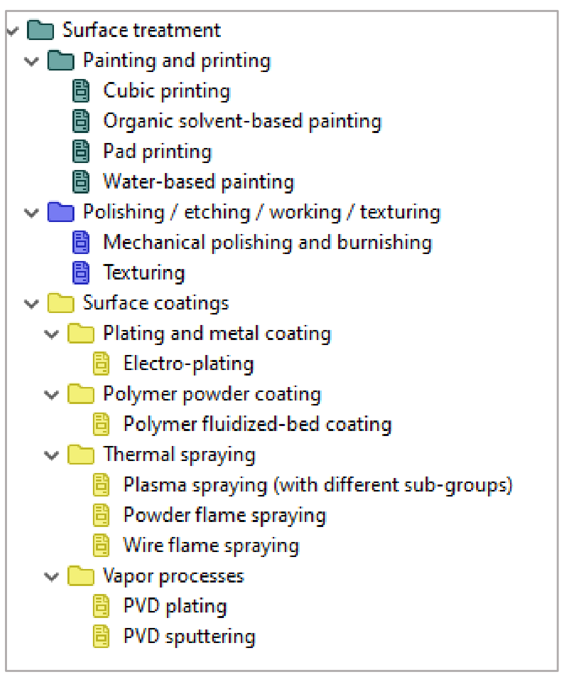

Figure 23

In figure 20, the joining process of the material have been shown. In figure 21 and 22, the Shaping process of the material has been shown and in figure 23 the surface treatment process has been shown.

- **Epoxy SMC (55% long Carbon fiber)**

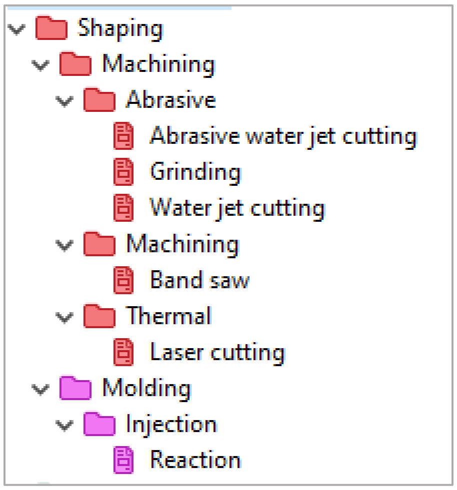

Figure 24

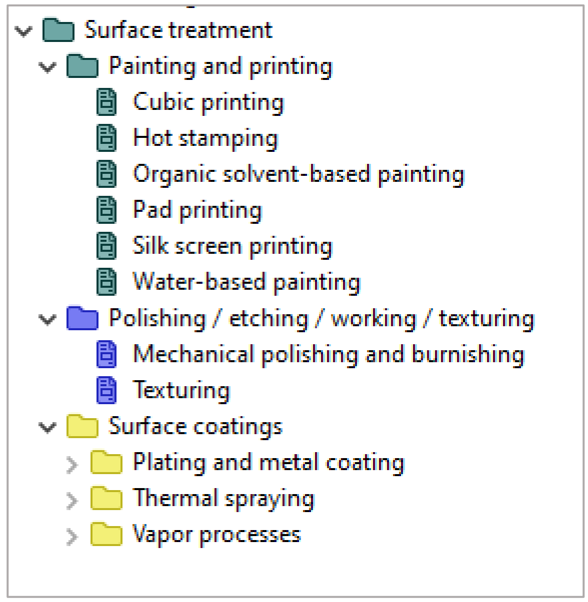

Figure 25

In this material there is no joining process. Figure 24 shows the shaping process and figure 25 shows the surface treatment process.

- Polyester BMC (10-20% glass fiber)

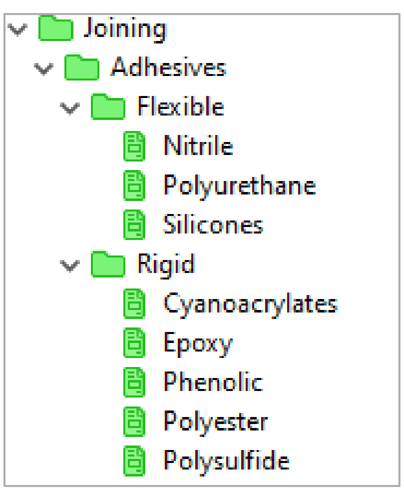

Figure 26

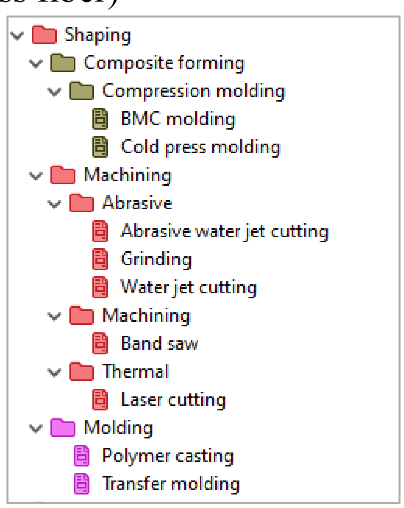

Figure 27

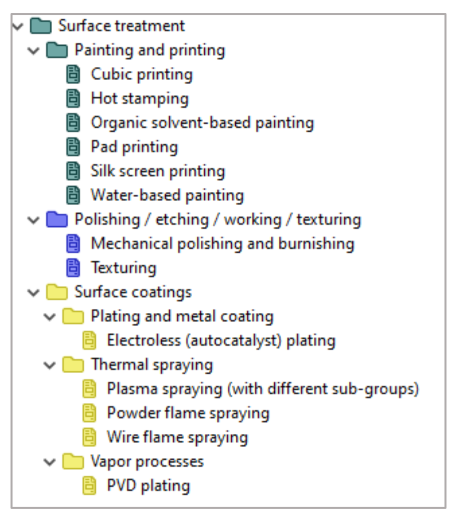

Figure 28

In figure 26 the joing process, in figure 27 the shaping process and in figure 28 surface treatment process have been shown.

Task 5.2.2

In this task it has been asked to choose three joining processes, three shaping processes, and three surface treatment processes and to make a table with these nine processes and the three example materials, indicating the suitability of each of those processes for each of those materials.

Table 9

Processes/ Material	**Al/Si Carbide**	**CFRP**	**DMC**
Joining Process			
Adhesive	Suitable	Suitable	Suitable
Fastener	Suitable	Suitable	Not Suitable
Mechanical Welding	Suitable	Not Suitable	Not Suitable
Shaping Process			
Composite forming	Not Suitable	Suitable	Suitable
Machining	Suitable	Suitable	Suitable
Deformation	Suitable	Not Suitable	Not Suitable
Surface Treatment			
Cubic Painting	Suitable	Suitable	Suitable
Grinding and Polishing	Suitable	Suitable	Polishing Suitable
Vapor Metallizing	Suitable	Suitable	Suitable

In table 9, using level 2 of Process universe the suitability of the three processes on the three material has been shown.

Table 10

Processes/ Material	Silicon Carbide - Al-47%SiC(f)	Epoxy SMC (55% long Carbon fiber)	Polyester BMC (10-20% glass fiber)
Joining Process			
Adhesive	Suitable	Not Suitable	Suitable
Fastener	Suitable	Not Suitable	Not Suitable
Mechanical Welding	Suitable	Not Suitable	Not Suitable
Shaping Process			
Composite forming	Not Suitable	Not Suitable	Suitable
Machining	Suitable	Suitable	Suitable
Deformation	Suitable	Not Suitable	Not Suitable
Surface Treatment			
Cubic Painting	Suitable	Suitable	Suitable
Grinding and Polishing	Suitable	Suitable	Polishing Suitable
Vapor Metallizing	Suitable	Suitable	Suitable

In table 10, using level 3 of the process universe the suitability of the nine process of three method on the three material has been shown.

The difference between the level 2 and level 3 has been noticied. While choosing similar material like CFRP in level 2, Epoxy SMC (55% long Carbon fiber) has been selected in level 3. In level 3, it has been seen that there is no joining process available for Epoxy SMC (55% long Carbon fiber). Moreover in shaping this material, composite forming was not available. Instead of composite forming molding was available.

Task 5.2.3

In this task it has been asked to choose one of the use cases that I considered for task 0_1 and to explain how such products are made. So, one of the materials that I had chosen was Metal Matrix Composite. One of the example is Al/Si Carbide. In automotive vehicle, the disk brake are made of Al/Si Carbide. The attraction of metal matrix composites such as Duralcan is their stiffness-to-weight and strength-to-weight ratios, allowing weight saving in automobiles and sports equipment.Metal matrix composites ('MMCs') are made by stirring finely divided silicon carbide (SiC) or alumina (Al2O3) particles into the molten metal, which is then cast ('Stir-casting'), or by mixing metal and ceramic powders and sintering, followed by forging or extrusion. The most widely used are the DURALCAN range of alloys based on the 6061 grade of aluminum alloy, with 10 to 30% silicon carbide or alumina.This are typically used in Pistons, engine parts, brake discs, drums and calipers, drive shafts, precision instruments and sports equipment such as mountain bike frames and golf club shafts.