MIDWOR - LIFE14 ENV/ES/000670

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PROJECT MIDWOR Deliverable C1

Report on environmental performance of the project's implementation

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[1] **Nature of Deliverable**: **P**= Prototype, **R**= Report, **S**= Specification, **T**= Tool, **O**= Other.

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1. Introduction

MIDWOR project aims to mitigate the environmental, health and safety impacts of current Durable Water and Oil Repellents (DWOR) and future alternatives by analyzing their environmental impact and technical performances in order to assess the best available products to provide repellency to liquids on textiles.

During the last decades DWOR chemistries based on polymeric perandpolyfluoroalkyl substances (PFASs), more precisely “side-chain fluorinated polymers”, have been common since side-chain fluorinated polymer DWORs are highly durable and both water and oil resistant (1). Conventional finishing products made of long chain fluorocarbon polymers are persistent and bioaccumulative. Many perfluorochemicals have already been listed in different European regulations to put emphasis on their risk for humans and the environment. These products have been used in the textile industry since many years ago and tentative to replace them has been done since 2000. Alternative products are currently proposed by different chemical companies for textile applications, however, the toxicity, environmental and economic impact of these new alternatives is still unknown. The substitution of toxic and persistent perfluorochemicals is of high importance as they occupy a high place in the market.

The present deliverable is aimed to compare the environmental impact produced during the finishing treatment of textiles between fluorinated DWORs (conventional products) and fluorine-free alternatives.

2. Methodology for evaluating the environmental impact

The environmental impact of the MIDWOR project has been determined by comparing a baseline scenario where fluorinated DWOR products are used, with the MIDWOR scenarios where fluorine-free products are encouraged to be applied.

The results of the Life Cycle Assessment (LCA) obtained in the pilot textile industries (Action B3 of the project) participating in the project have been used to determine the impact on the environment of the replacement of fluorinated DWORs by fluorine-free alternatives. The system boundaries considered in the LCA is the textile finishing process. The whole life cycle of DWOR products has been considered.

The methodology applied is the LCA methodology. The base methodology chosen for the impact assessment is the ILCD method. The ILCD 2011 Midpoint method was released by the European Commission, Joint Research Centre in 2012. It supports the correct use of the characterisation factors for impact assessment as recommended in the ILCD guidance document "Recommendations for Life Cycle Impact Assessment in the European context - based on existing environmental impact assessment models and factors[3]. This LCIA method includes 16 midpoint impact categories. The main limitations and assumptions considered in the definition of the LCA model can be consulted in the Action B3 report of MIDWOR project. For this study, the following environmental impact indicators have been selected to be considered relevant for the system studied. Detailed information on this impact categories are detailed in **¡Error! No se encuentra el origen de la referencia.**.

Impact category	Description	Model/ Method
Climate change	Global Warming Potential calculating the radiative forcing over a time horizon of 100 years.	IPCC 2007
Ozone depletion	Ozone Depletion Potential (ODP) calculating the destructive effects on the stratospheric ozone layer over a time horizon of 100 years.	WMO 1999.
Human toxicity, cancer effects	Comparative Toxic Unit for humans (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogramme). Specific groups of chemicals require further works.	USEtox.
Human toxicity, non-cancer effects	Comparative Toxic Unit for humans (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogramme). Specific groups of chemicals require further works.	USEtox.
Freshwater ecotoxicity	Comparative Toxic Unit for ecosystems (CTUe) expressing an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a	USEtox.

[3] The ILCD 2011 Midpoint method was released by the European Commission, Joint Research Centre in 2012. It supports the correct use of the characterisation factors for impact assessment as recommended in the ILCD guidance document "Recommendations for Life Cycle Impact Assessment in the European context - based on existing environmental impact assessment models and factors

	chemical emitted (PAF m3 year/kg). Specific groups of chemicals require further works.	
Mineral, fossil & renewable resource depletion	Scarcity of mineral resource with the scarcity calculated as 'Reserve base'. It refers to identified resources that meet specified minimum physical and chemical criteria related to current mining practice. The reserve base may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics.	van Oers et al. 2002.

TABLE 1. ENVIRONMENTAL IMPACT INDICATORS SELECTED

The results obtained from the Life Cycle Assessment developed during the project (more information in the deliverable B3) have been used to perform the extrapolation of the environmental impact of using fluorinated and non-fluorinated DWOR products at EU level.

3. Definition of the scenarios

Different considerations have been used to make the extrapolation of the LCA results. First of all, the Functional Unit (FU) used during the LCA has been defined: 100 m^2 of finished fabric. Data related with the FU is needed to calculate the environmental impact at European level.

According to Eurostat, 3065 finishing textile companies are located in Italy, Spain and Czech Republic (countries participating in the project).

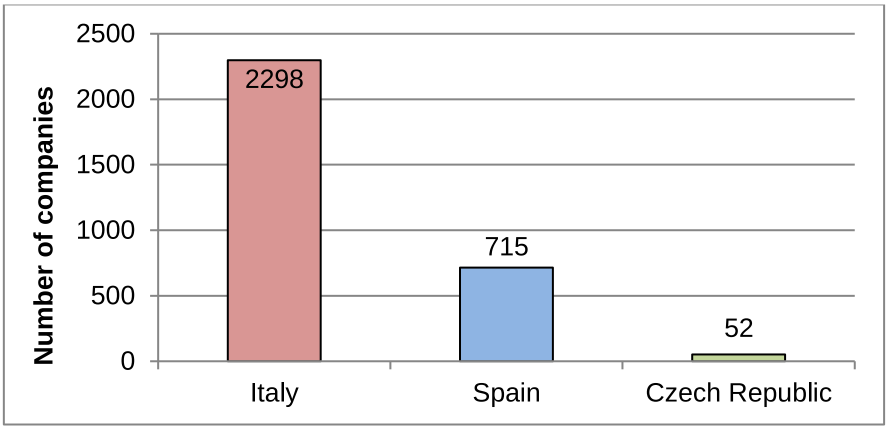

FIGURE 1: NUMBER OF FINISHING TEXTILE COMPANIES LOCATED IN ITALY, SPAIN AND CZECH REPUBLIC

According to data collected during the project and consultations made to stakeholders involved, 75% of finishing textile companies apply DWOR treatments: 2299 companies. Regarding the companies applying DWOR treatments, 83.3% of them apply fluorinated DWORs: **1915 companies located in Italy, Spain and Czech Republic are applying DWOR treatments**.

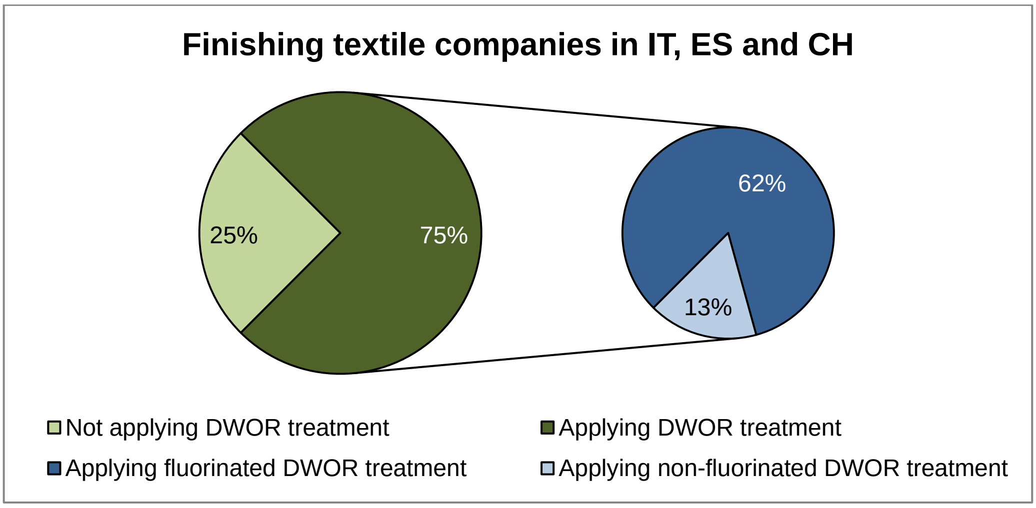

FIGURE 2: DISTRIBUTION OF FINISHING TEXTILE COMPANIES BY TYPE OF TREATMENT

Finally, it was assumed according to data collected during the project that 6000 m^2 of fabrics are treated with DWOR products per year in a company.

In the table below, data considered in the baseline scenario are presented.

Baseline scenario		
Fabrics treated with DWOR products	13.792.500 m^2/year	
Fabrics treated with fluorinated DWOR	83,3% →	**11.489.153 m^2/year**
Fabrics treated with non-fluorinated DWOR	16,7% →	**2.303.348 m^2/year**

TABLE 2: SUMMARY OF THE DATA CONSIDERED IN THE BASE LINE SCENARIO

In order to compare the potential environmental impact of the replacement of conventional DWORs by the alternative products, different scenarios have been considered increasing the percentage of fabrics treated with non-fluorinated DWOR:

Scenario 1: 10% more of textiles treated with fluorine-free DWOR products		
Fabrics treated with DWOR products	13.792.500 m^2/year	
Fabrics treated with fluorinated DWOR	73,3% →	**10.109.903 m^2/year**
Fabrics treated with non-fluorinated DWOR	26,7% →	**3.682.598 m^2/year**
Scenario 2: 20% more of textiles treated with fluorine-free DWOR products		
Fabrics treated with DWOR products	13.792.500 m^2/year	
Fabrics treated with fluorinated DWOR	63,3% →	**8.730.650 m^2/year**
Fabrics treated with non-fluorinated DWOR	36,7% →	**5.061.848 m^2/year**
Scenario 3: 40% more of textiles treated with fluorine-free DWOR products		
Fabrics treated with DWOR products	13.792.500 m^2/year	
Fabrics treated with fluorinated DWOR	43,3% →	**5.972.153 m^2/year**
Fabrics treated with non-fluorinated DWOR	56,7% →	**7.820.348 m^2/year**
Scenario 4: 60% more of textiles treated with fluorine-free DWOR products		
Fabrics treated with DWOR products	13.792.500 m^2/year	
Fabrics treated with fluorinated DWOR	23,3% →	**3.213.653 m^2/year**
Fabrics treated with non-fluorinated DWOR	76,7% →	**10.578.848 m^2/year**

TABLE 3: DATA CONSIDERED IN THE IMPROVEMENT SCENARIOS

4. Environmental impact of MIDWOR project

This chapter presents the results for the baseline scenario and for the MIDWOR scenarios considered.

The baseline scenario of the model covered fluorinated products, including 4 types of DWOR products: C8-based products, short chain fluorocarbon C6, C6 fluorosilicone and perflurosilicones. Three additional DWOR product types were addressed as improvement options in the MIDWOR scenario: silicone, dendrimer based product and paraffins. Table 4 recapitulates which types of DWOR products were addressed in the model.

DWOR classification	DWOR finishing products selected
Fluorinated products	Long chain fluorocarbon C8 (FC-C8)
	Short chain fluorocarbon C6 (FC-C6)
	C6 fluorosilicone (C6(FSi))
	Perfluorosilicone (PFSi)
Fluorine-free products	Silicone
	Dendrimer based product (Hyper branched polymer)
	Paraffin (Polyethylene and amiloplast wax)[4]

TABLE 4: DWOR PRODUCT TYPES USED IN THE BASELINE SCENARIO AND IN THE EVALUATION OF THE ALTERNATIVE SCENARIO (MIDWOR SCENARIO)

In the next table, a summary of the results per FU (100m^2 of textile) of the LCA is presented.

Impact category	Fluorinated substances			Non-fluorinated substances		
	C8 based product	C6 based product	Perfluoro-silicone	Silicone	Dendrimer	Paraffin
Climate Change (kg CO2 eq)	4,89E+02	6,06E+02	7,08E+02	1,37E+02	8,82E+01	8,91E+01
Ozone Depletion (kg CFC-11 eq)	1,18E-02	1,52E-02	1,80E-02	2,66E-05	8,51E-06	7,96E-06
Human toxicity, non-cancer effects (CTUh)	1,35E-04	1,96E-05	2,24E-05	2,79E-05	1,28E-05	1,06E-05
Human toxicity, cancer effects (CTUh)	1,97E-05	3,39E-06	3,77E-06	5,14E-06	2,65E-06	2,34E-06
Fresh water ecotoxicity (CTUe)	5,94E+02	4,86E+02	5,56E+02	7,06E+02	2,87E+02	2,81E+02
Resource depletion (kg Sb eq)	1,54E-02	1,96E-02	2,31E-02	4,69E-03	1,58E-03	1,78E-03

TABLE 5: SUMMARY OF THE RESULTS OBTAINED DURING THE LIFE CYCLE ASSESSMENT

[4] Only tested at laboratory scale

This data has been used to calculate the potential environmental impacts of the different scenarios considered. The results of the different scenarios are presented in Table 6.

	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Climate Change (kg CO2 eq)	7,15E+07	6,46E+07	5,78E+07	4,41E+07	3,04E+07
Ozone Depletion (kg CFC-11 eq)	1,72E+03	1,52E+03	1,31E+03	8,96E+02	4,83E+02
Human toxicity, non-cancer effects (CTUh)	7,18E+00	6,60E+00	6,02E+00	4,86E+00	3,71E+00
Human toxicity, cancer effects (CTUh)	1,11E+00	1,03E+00	9,54E-01	8,00E-01	6,45E-01
Fresh water ecotoxicity (CTUe)	7,24E+07	7,08E+07	6,91E+07	6,58E+07	6,24E+07
Resource depletion (kg Sb eq)	2,29E+03	2,06E+03	1,83E+03	1,37E+03	9,07E+02

TABLE 6: ENVIRONMENTAL IMPACT OF SCENARIOS SELECTED PER IMPACT CATEGORY

For all the impact categories analysed the environmental impact of the baseline scenario is higher than for the MIDWOR scenarios considered. In the next figures, the results are represented by impact category.

The improvement potential depends on the impact category analysed. The impact category with a higher reduction of the environmental impact is the ozone depletion: the environmental impact reduction is more than 70% if the scenario 4 is considered (increasing the percentage of textiles treated with fluorine-free DWOR products until 76,7%). If is considered a substitution in 10% of textiles, the environmental impact at European level could be reduced in 12%.

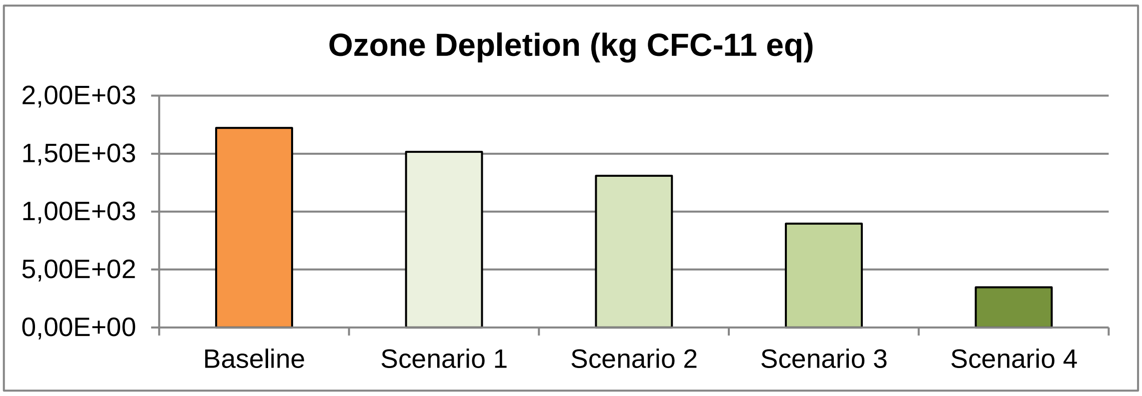

FIGURE 3: ENVIRONMENTAL IMPACT OF THE DIFFERENT SCENARIOS CONSIDERED FOR THE IMPACT CATEGORY OZONE DEPLETION

For Climate Change impact category, the environmental impact reduction goes from 10% to 60% according the percentage of textiles treated with fluorinate-free DWOR products (Figure 4). Human toxicity, cancer and non-cancer effects, impact categories have a maximum impact reduction of 40% and 50% respectively (Figure 5 and Figure 6). Finally, a reduction between 10-60% is achieved in the resource depletion impact category (Figure 7).

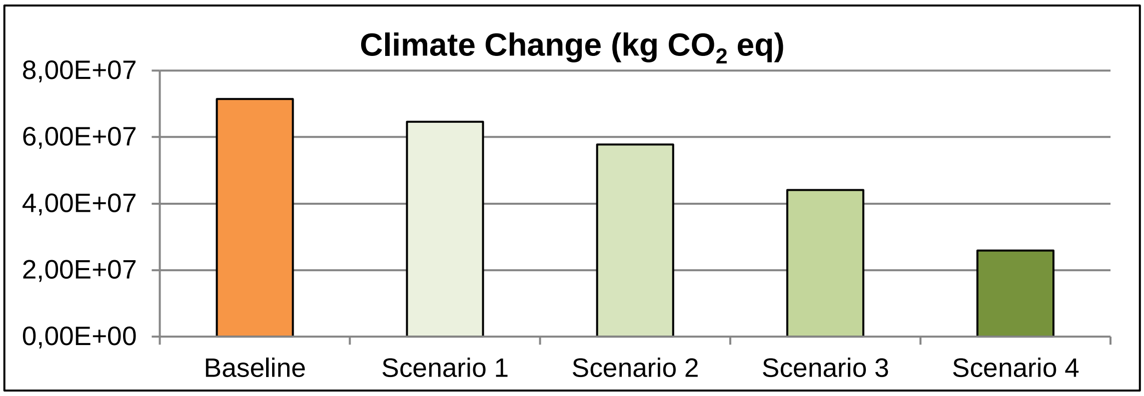

FIGURE 4: ENVIRONMENTAL IMPACT OF THE DIFFERENT SCENARIOS CONSIDERED FOR THE IMPACT CATEGORY CLIMATE CHANGE

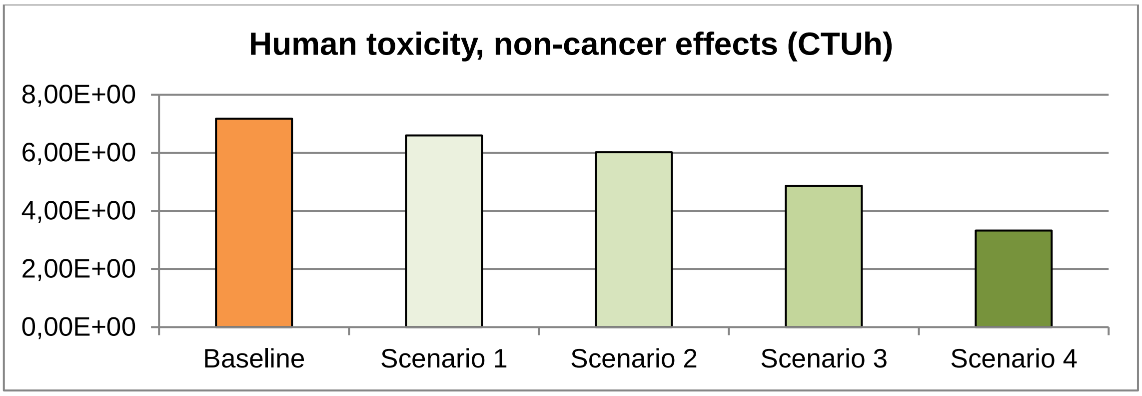

FIGURE 5: ENVIRONMENTAL IMPACT OF THE DIFFERENT SCENARIOS CONSIDERED FOR THE IMPACT CATEGORY HUMAN TOXICITY, NON-CANCER EFFECTS

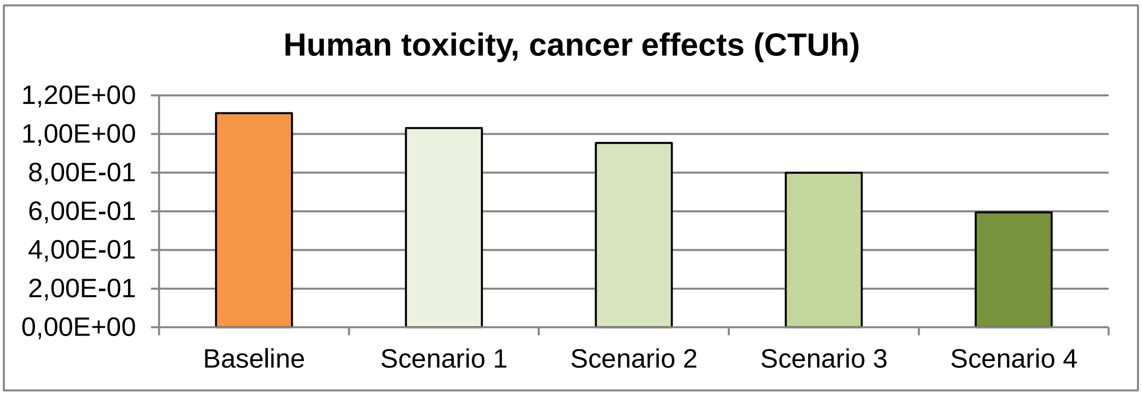

FIGURE 6: ENVIRONMENTAL IMPACT OF THE DIFFERENT SCENARIOS CONSIDERED FOR THE IMPACT CATEGORY HUMAN TOXICITY, CANCER EFFECTS

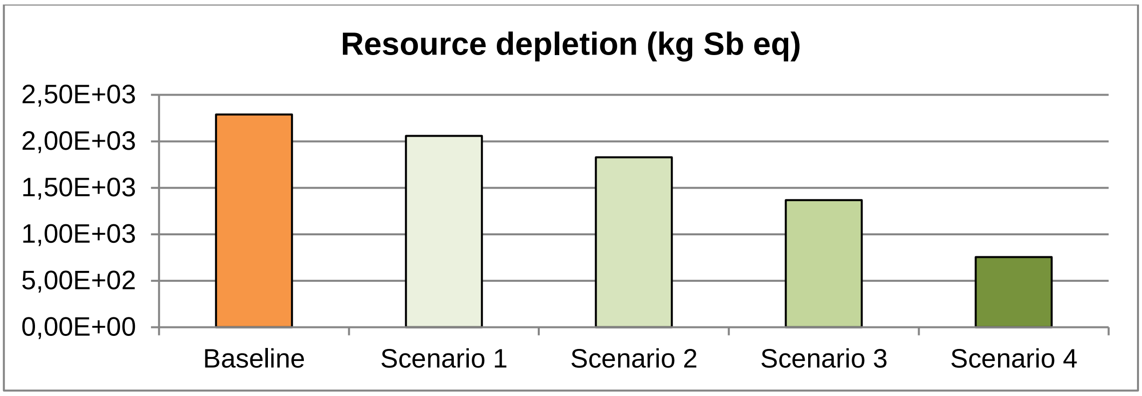

FIGURE 7: ENVIRONMENTAL IMPACT OF THE DIFFERENT SCENARIOS CONSIDERED FOR THE IMPACT CATEGORY RESOURCE DEPLETION

The less affected impact category is the freshwater ecotoxicity, with an impact reduction of 3% for the Scenario 1: 10% of the textiles usually treated with conventional DWOR have been treated with the alternative products analysed during MIDWOR project. Considering 60% more of textiles treated with fluorine-free DWOR products than the baseline scenario, is achieved an impact reduction of 14%.

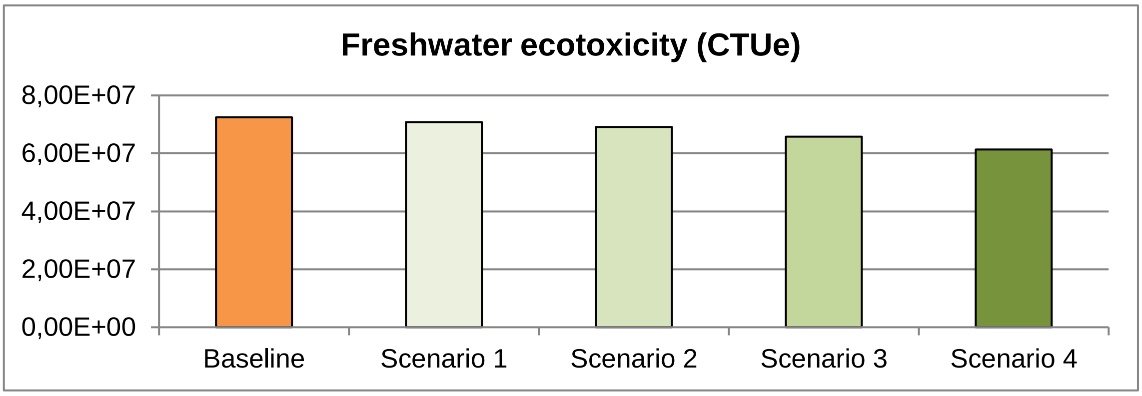

FIGURE 8: ENVIRONMENTAL IMPACT OF THE DIFFERENT SCENARIOS CONSIDERED FOR THE IMPACT CATEGORY FRESH WATER ECOTOXCITY

Due to the consumption of DWOR at European level is high, the improvement achieved is important even if small fraction of finishing textile industries substitute their substances. The emissions avoided in Europe of CO_2 could reach 23.000 tons annually, if 40% of the fluorinated DWOR are substituted.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
CO_2 eq emissions avoided (tons)	6.841,8	13.683,6	27.367,1	41.050,7

TABLE 7: CO_2 EMISSIONS AVOIDED WITH THE SUBSTITUTION OF FLUORINATED DWOR

4.1. Improvement scenario 1

When the baseline scenario is compared with the scenario 1, where 10% of the fluorinated substances are substituted by alternative substances tested in MIDWOR project, the reduction of the environmental impact is still important, reaching a benefit of 12% in some impact categories selected. In Table 8 a summary of the environmental benefits obtained due to a reduction of 10% in fluorinated consumption is presented.

Impact category	Baseline Scenario		Scenario 1
Climate change	7,15E+07	↓ 9,6%	6,46E+07
Ozone depletion	1,72E+03	↓ 12,0%	1,52E+03
Human toxicity, non-cancer effects	7,18E+00	↓ 8,1%	6,60E+00
Human toxicity, cancer effects	1,11E+00	↓ 7,0%	1,03E+00
Freshwater ecotoxicity	7,24E+07	↓ 2,3%	7,08E+07
Mineral, fossil & renewable resource depletion	2,29E+03	↓ 10,1%	2,06E+03

TABLE 8: ENVIRONMENTAL BENEFITS OBTAINED DUE TO THE SUBSTITUTION OF 10% OF FLUORINATED DWOR IN FINISHING TREATMENTS

4.2. Improvement scenario 2

The scenario 2 supposes an increase of 20% of the textiles treated with non-fluorinated DWOR. The environmental benefits obtained vary depending on the impact category, for ozone depletion impact category, the improvement obtained reaches the 24%. On the other hand, for freshwater ecotoxicity only 4% of reduction is achieved.

Impact category	Baseline Scenario		Scenario 2
Climate change	7,15E+07	↓ 19,2%	5,78E+07
Ozone depletion	1,72E+03	↓ 24,0%	1,31E+03
Human toxicity, non-cancer effects	7,18E+00	↓ 16,1%	6,02E+00
Human toxicity, cancer effects	1,11E+00	↓ 13,9%	9,54E-01

Freshwater ecotoxicity	7,24E+07	⇩ 4,6%	6,91E+07
Mineral, fossil & renewable resource depletion	2,29E+03	⇩ 20,1%	1,83E+03

TABLE 9: ENVIRONMENTAL BENEFITS OBTAINED DUE TO THE SUBSTITUTION OF 10% OF FLUORINATED DWOR IN FINISHING TREATMENTS

4.3. Improvement scenario 3

Table 10 presents a summary of the environmental benefits obtained due to the use of non-fluorinated DWOR in 56,7% of the treated textiles. The improvement potentials go from 9,2% to 48%.

Impact category	Baseline Scenario		Scenario 3
Climate change	7,15E+07	⇩ 38,3%	4,41E+07
Ozone depletion	1,72E+03	⇩ 48,0%	8,96E+02
Human toxicity, non-cancer effects	7,18E+00	⇩ 32,2%	4,86E+00
Human toxicity, cancer effects	1,11E+00	⇩ 27,8%	8,00E-01
Freshwater ecotoxicity	7,24E+07	⇩ 9,2%	6,58E+07
Mineral, fossil & renewable resource depletion	2,29E+03	⇩ 40,3%	1,37E+03

TABLE 10: ENVIRONMENTAL BENEFITS OBTAINED DUE TO THE SUBSTITUTION OF 10% OF FLUORINATED DWOR IN FINISHING TREATMENTS

4.4. Improvement scenario 4

Finally, in Table 11 a summary of the impact reduction achieved in the scenario 4 is presented. The scenario 4 assumes the use of non-fluorinated DWOR in 76,7% of the textiles treated.

Impact category	Baseline Scenario		Scenario 4
Climate change	7,15E+07	⇩ 57,5%	3,04E+07
Ozone depletion	1,72E+03	⇩ 71,9%	4,83E+02
Human toxicity, non-cancer effects	7,18E+00	⇩ 48,4%	3,71E+00

Human toxicity, cancer effects	1,11E+00	↓ 41,8%	6,45E-01
Freshwater ecotoxicity	7,24E+07	↓ 13,8%	6,24E+07
Mineral, fossil & renewable resource depletion	2,29E+03	↓ 60,4%	9,07E+02

TABLE 11: ENVIRONMENTAL BENEFITS OBTAINED DUE TO THE SUBSTITUTION OF 10% OF FLUORINATED DWOR IN FINISHING TREATMENTS

5. Conclusions

This report aims to assess the environmental benefits obtained at European level due to the substitution of the fluorinated DWOR in finishing treatment of textiles. An estimation of the textile treated in the studied countries has been done in order to up-scale the results obtained in the LCA developed during the project.

Oil repellency should be treated with fluorinated DWORs, for this reason the use of non-fluorinated DWOR for treat all fabrics is not possible. However, fluorine-free alternatives should be used for applications where water repellency alone is required, since are preferable from the environmental and human health point of view.

Different scenarios have been defined to analyse the improvements at European level:

- Scenario 1: 10% more of textiles treated with fluorine-free DWOR products
- Scenario 2: 20% more of textiles treated with fluorine-free DWOR products
- Scenario 3: 40% more of textiles treated with fluorine-free DWOR products
- Scenario 4: 60% more of textiles treated with fluorine-free DWOR products

The use of alternative substances in finishing textile industry means a reduction of the environmental impact for all the impact categories. The percentage of improvement depends on the impact category assessed and the scenario considered. If 10% of the substances are substituted, the reduction of the environmental impact achieve

It is important to consider, that at European level the avoided impacts are important since the consumption of this type of substances is extensively used in the textile industry, and are related with a high environmental impact.

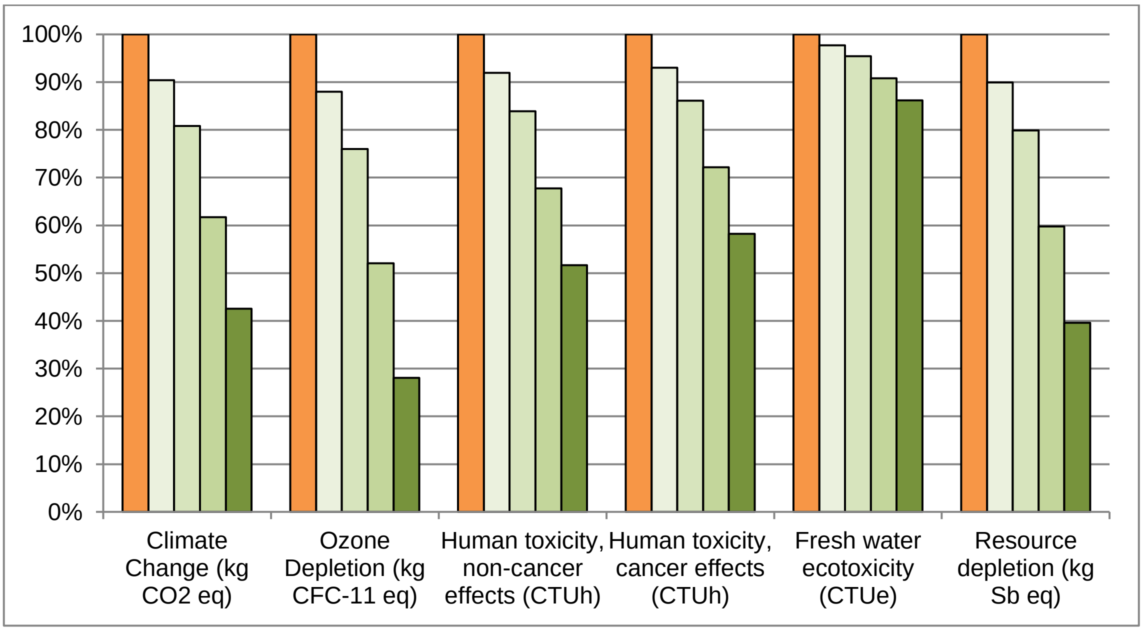

FIGURE 9: SUMMARY OF THE IMPROVEMENTS REACHED WITH THE SUBSTITUTION OF FLUORINATED DWOR