TOWEF0

(Toward Effluent Zero)

EVALUATION OF THE EFFECT OF THE IPPC APPLICATION ON THE SUSTAINABLE WASTE MANAGEMENT IN TEXTILE INDUSTRIES

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General conclusions of LCA studies and analysis of innovative water management scenarios.

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1 Introduction

The work documented in this report is part of the project "Evaluation of the effect of the IPPC application on the sustainable waste water management in textile industries (Towef0)" funded by European Commission as a shared cost RTD project in the 5^{th} Framework Research program, Energy, Environment and Sustainable Development, Key action 1 Sustainable Management and Quality of Water, Treatment and purification technologies, Waste water treatment and reuse.

The project objective is to establish a multicriteria integrated and coherent implementation of Good Environmental Practices (GEP) and to promote the efficient use of resources within textile finishing industries characteriziszed by large use of water, taking into account the treatment of industrial waste water effluent (Urban Waste Water Treatment Directive 91/271 EEC) and the impact of the final discharge to the water recipient bodies (Water Framework Directive COM (98)).

Within this framework ENEA-PROT-INN conducted detailed LCA studies on selected Italian and Belgian industries in order to estimate the potential impact on the environment of specific company processes, evaluate the environmental effects of alternatives scenarios of water management and develop a database of Life Cycle Inventories of textile production processes and chemicals.

Partners of the project were: ENEA, the Italian National Agency for New Technologies, Energy and the Environment, Vito, a Belgian research centre for the industry, Centexbel, a research centre for the Belgian textile federation, the Joint research Centres of Siviglia and Ispra, Lariana Depur S.p.A., a private Italian company, Ecobilan, a private French company and Lettinga Associates Foundation (LeAF), a Dutch foundation for environmental protection and resource conservation.

In this document the main results of the analyses conducted within the selected textile companies are synthesized and discussed and the results of LCA of innovative water management scenarios are presented.

2 General results of LCA studies

The LCA studies were performed in seven Italian and Belgian companies with the following main aims:

- To build up LCA models for identifying the environmental critical points;
- To develop a database of LCI of textile processes and products to be used with a user friendly software developed by Ecobilan;
- To support the choice of water saving scenarios verifying if the adoption of water saving techniques can transfer pollution from water to other environmental media.

Table 2.1 shows the products analysed within each company.

Report	Company	Product
TM-108-003 Rev0	I02	Viscose fabric
TM-108-005 Rev0	I04	Viscose fabric
TM-108-002 Rev1	I06	Flax-PES fabric
TM-108-004 Rev1	I09	Silk yarn
TM-108-006 Rev0	I15	Silk fabric
TM-108-008 Rev0	B05	Cotton-PES Fabric
TM-108-007 Rev0	B02	Cotton fabric

Tab 2.1 Selected textile companies.

In the following paragraphs the main contributors to all impact category are discussed in more detail. The B02 company has not been included in the analysis because less detailed inventory data were available.

2.1 Contribution analysis

In the following tables the contribution analysis to the selected environmental impact categories is presented for each company.

I02 environmental impact categories	Steam production	Electricity production	Others
CML-Air Acidification	8%	77%	10%
CML-Aquatic Eco-toxicity	34%	56%	10%
CML-Depletion of non renewable resources	68%	23%	10%
CML-Eutrophication	3%	7%	87%
CML-Human Toxicity	7%	83%	10%
CML-Terrestrial Eco-toxicity	76%	10%	14%
IPCC-Greenhouse effect (direct, 100 years)	50%	40%	10%
WMO-Photochemical oxidant formation (high)	24%	53%	6%

Figure 2.1.1 Contribution to potential environmental impacts for I02 company

I04 environmental impact categories	Steam production	Electricity production	Others
CML-Air Acidification	14%	78%	8%
CML-Aquatic Eco-toxicity	48%	46%	6%
CML-Depletion of non renewable resources	82%	16%	2%
CML-Eutrophication	12%	17%	71%
CML-Human Toxicity	11%	81%	8%
CML-Terrestrial Eco-toxicity	92%	7%	1%
IPCC-Greenhouse effect (direct, 100 years)	66%	31%	3%
WMO-Photochemical oxidant formation (high)	40%	52%	7%

Figure 2.1.2 Contribution to potential environmental impacts for I04 company

I06 environmental impact categories	Steam production	Electricity production	Others
CML-Air Acidification	9%	59%	0%
CML-Aquatic Eco-toxicity	41%	43%	7%
CML-Depletion of non renewable resources	72%	16%	13%
CML-Eutrophication	13%	21%	0%
CML-Human Toxicity	8%	63%	0%
CML-Terrestrial Eco-toxicity	90%	8%	6%
IPCC-Greenhouse effect (direct, 100 years)	59%	30%	0%
WMO-Photochemical oxidant formation (high)	30%	44%	0%

Figure 2.1.3 Contribution to potential environmental impacts for I06 company

I09 environmental impact categories	Steam production	Electricity production	Others
CML-Air Acidification	24%	47%	29%
CML-Aquatic Eco-toxicity	55%	18%	26%
CML-Depletion of non renewable resources	89%	6%	5%
CML-Eutrophication	9%	4%	87%
CML-Human Toxicity	20%	50%	31%
CML-Terrestrial Eco-toxicity	97%	3%	1%
IPCC-Greenhouse effect (direct, 100 years)	80%	13%	8%
WMO-Photochemical oxidant formation (high)	47%	21%	32%

Figure 2.1.4 Contribution to potential environmental impacts for I09 company

I15 environmental impact categories	Steam production	Electricity production	Others
CML-Air Acidification	41%	50%	9%
CML-Aquatic Eco-toxicity	81%	16%	2%
CML-Depletion of non renewable resources	95%	4%	1%
CML-Eutrophication	22%	6%	72%
CML-Human Toxicity	38%	58%	4%
CML-Terrestrial Eco-toxicity	98%	2%	0%
IPCC-Greenhouse effect (direct, 100 years)	89%	9%	3%
WMO-Photochemical oxidant formation (high)	74%	20%	6%

Figure 2.1.5 Contribution to potential environmental impacts for I15 company

B05 environmental impact categories	Steam production	Electricity production	Others
CML-Air Acidification	60%	0%	40%
CML-Aquatic Eco-toxicity	96%	0%	4%
CML-Depletion of non renewable resources	95%	0%	5%
CML-Eutrophication	24%	0%	76%
CML-Human Toxicity	60%	0%	40%
CML-Terrestrial Eco-toxicity	100%	0%	0%
IPCC-Greenhouse effect (direct, 100 years)	95%	0%	5%
WMO-Photochemical oxidant formation (high)	86%	0%	14%

Figure 2.1.6 Contribution to potential environmental impacts for B05 company

In all companies, steam production is a “hot spot” for several “energy related” impact categories (greenhouse effect, terrestrial and aquatic ecotoxicity and depletion of natural resources). Electric energy production is the dominant pollutant source mainly for acidification and human toxicity categories, because of heavy use of fossil fuels for the production of electric energy in Italy. The only exception is B05 company in which production of electricity is not a significant issue. In fact most of the electricity consumed in B05 company is related to a big weaving department that is outside the system boundaries of the LCA study. The analysed processes have relatively low electricity consumptions.
The main contributor to eutrophication is the external waste water treatment plant, because it includes the potential impact of the release to the environment of the treated effluents.

2.2 Water consumption

The water needed to treat 100 kg of products ranges between 5 and 42 cubic meters. (Figure 2.2.1).These differences depend on the type of the processes, the used equipment and the selected fabric. The water used outside the company in all the phases of the life cycle included in the system boundaries is always a small part of the total.

Water consumption (gate to gate) per 100kg of product

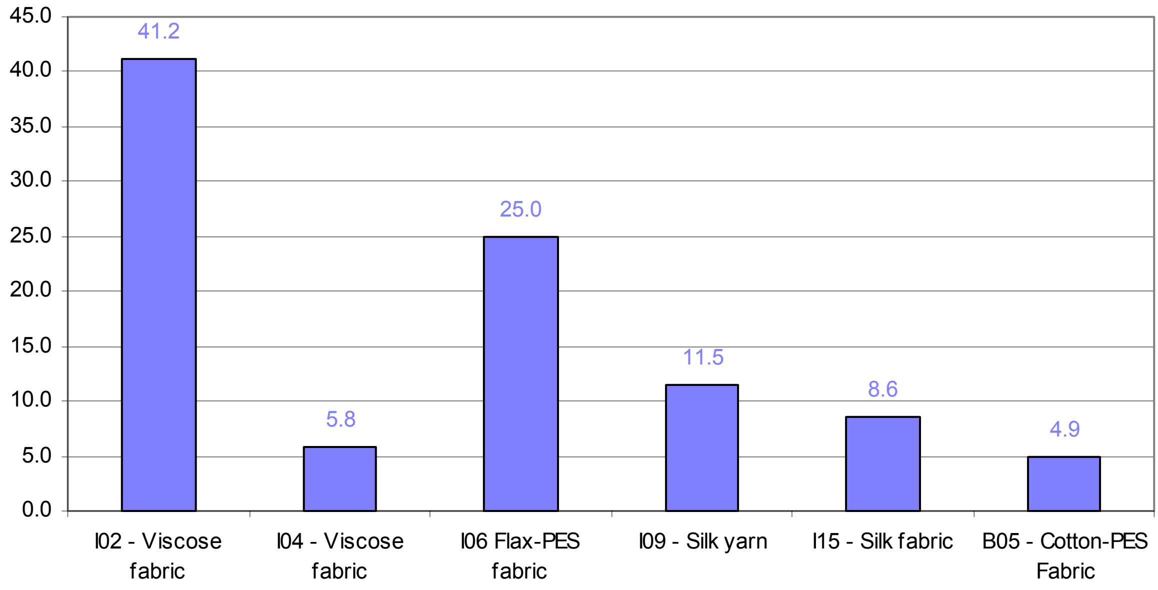

Figure 2.2.1 Water consumption for 100kg of product

The following table shows, for each company, the process with the main consumption of water. In general it is a dyeing process or a pretreatment one.

Company	Process	Water Consumption (m^3)
I02	washing	26
I04	dyeing	2.3
I06	flax and Pes dyeing	17
I09	dark acid dyeing	7
I15	scouring	7
B05	combined dyeing	2.5

Tab 2.2.1 Process with the main water consumption for each company.

2.3 Chemical production

The impact of chemicals production is a small but not negligible fraction of the textile products life cycle impact for all the environmental impact categories.
In case of lack of data, production of chemicals was excluded from LCA system. Chemicals were treated as flows and characterised in the impact assessment by means of EDIP method. Anyway chemicals with specific environmental risk phrases R50, R51, R52, R54, R55, R56 and R57 have not been used in any Italian analysed product chain.
It must be highlighted that often the LCA studies have a relevant lack of data on chemicals production with a range between 49% -95%. To check the impact of this incompleteness a sensitivity check was made using surrogate inventory data on the production of inorganic chemicals. Almost all systems are sensitive (in terms of per cent increase), for some energy indicators (feedstock energy, renewable energy, electricity), to the lack of data on chemicals. This effect can be explained because these energy indicators have in general low absolute

values and so also the small increase in the energy consumption caused by chemical production can produce significant per cent variations.
Anyway the evidenced lack of data on ecoprofiles of chemicals production does not impact the results of the studies on innovative water management scenarios.

2.4 Energy consumption

Primary energy is the energy embodied in natural resources (e.g. coal, crude oil, natural gas, uranium) that has not undergone any anthropogenic conversion or transformation. Primary energy consumption is an indicator of the efficiency of the use of energy natural resources in the overall system. In our studies it ranges between 2200 and 24000 MJ per 100 kg of product (Figure 2.4.1)
The observed great variability of energy consumption depends on the type of the processes, the used equipment and the selected fabric.

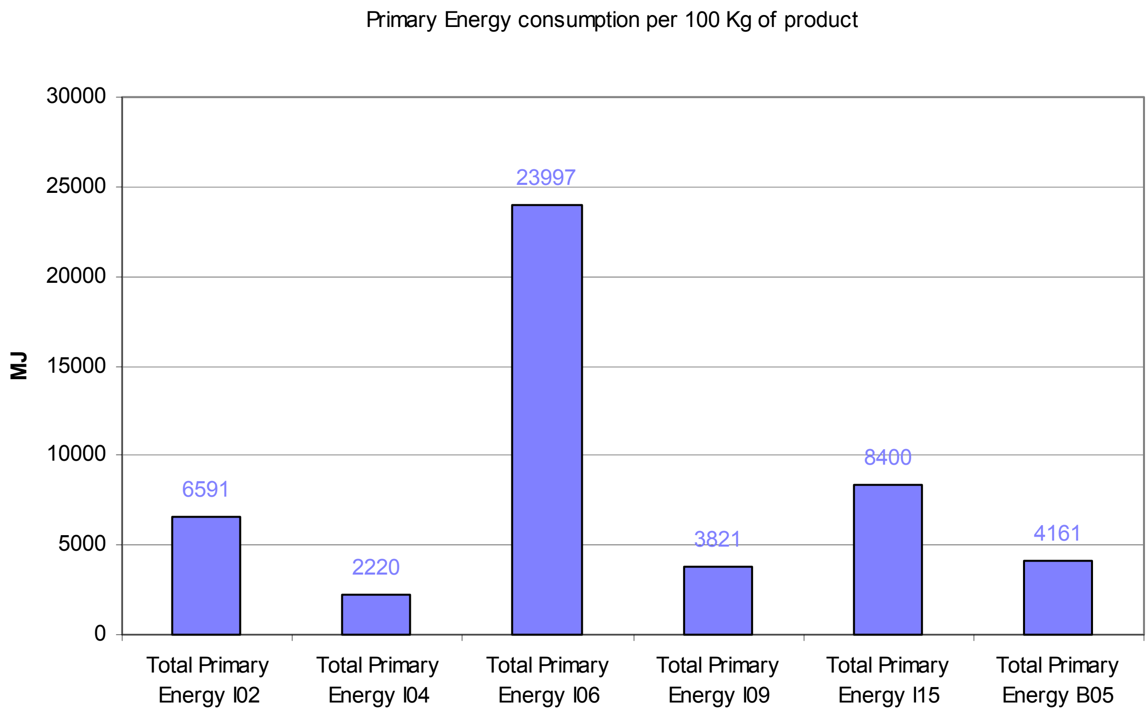

Figure 2.8 Primary energy consumption per 100 kg of product

The primary energy consumption is related to the quantity of fossil fuels burned mainly for steam production and in second place for electricity production. (Table. 2.4.1)

Primary Energy	Steam Production	Electricity Production	Others
I02	60%	29%	11%
I04	75%	25%	3%
I06	65%	29%	6%
I09	82%	10%	8%
I15	91%	7%	2%
B05	95%	0%	5%

Table 2.4.1 Contribution analysis to Primary Energy consumption

The process with the main consumption of primary energy is different for all companies, as shown in table 2.4.2

Company	Process	Primary energy consumption (MJ)
I02	steaming	3400
I04	soaping	647
I06	dyeing	1800
I09	Ht scouring	2200
I15	scouring	6700
B05	Steam production	3900

Tab 2.4.2 Process with the main primary energy consumption for each company.

3 Innovative water management scenarios

According to water pinch analysis findings (VITO) and relying on the results of pilot scale experiments (ultrafiltration, nanofiltration and reverse osmosis) conducted by projects partners, innovative water management scenarios were selected in each company and analysed by LCA methodology.
This approach can ensure that an optimal management of water in the production phase does not cause an overall increase in energy and raw material consumption or do not give raise to a pollution transfer from water to other environmental media (soil, air).
The proposed optimised scenarios are based on the nanofiltration treatment and reuse of the more diluted textile process effluents, according to the membrane treatment results. Treatment and reuse is department based (all preparation or dyeing effluents are treated in the same plant and reused in the preparation or dyeing processes) .
Furthermore the results of pilot scale experiments showed that:

- only less polluted process effluents can be effectively treated by nanofiltration to produce permeates suitable for reuse;
- the single ultrafiltration treatment does not normally assure a quality of the permeates suitable for reuse;
- all type of water can be treated by reverse osmosis to produce permeates suitable for reuse, but the economical evaluations led to very high costs.

So two types of innovative scenarios were defined:

1. “**Innovative scenario**”: ultrafiltration and nanofiltration technologies were applied to selected wastewater flows (mainly washing, rinsing and filling water);
2. “**Effluent zero scenario**”: ultrafiltration and reverse osmosis were applied only in one company to all textile processes effluents except finishing ones.

3.1 Selection of scenarios

To allow a comparison with the “reference” scenarios, it was decided to focus on the products already analysed by LCA studies conducted by ENEA in the Italian companies.
The following table shows the selected scenarios.

Company	System	Processes	Waste water treatment	Reusable Water
I02	A-electronic table reactive printing	F.4.3 Printing	Reverse Osmosis and ultrafiltration	Using reverse osmosis (effluent zero scenario)
		H.1.3 Fabric washing	Reverse Osmosis and ultrafiltration	Using reverse osmosis (effluent zero scenario)
		I.1 Water finishing		No water reuse
I04	A	F.1.1 Continuos scouring in mezzera	Ultrafiltration and Nanofiltration	Reuse only filling and rinsing water
		G.3.2 Dark direct dyeing in jigger	Ultrafiltration and Nanofiltration	Reuse only water from continuous rinsing
		G.13.1 Soaping in pad-steam	Ultrafiltration and Nanofiltration	Reuse only rinsing, discharge, neutralisation water
		H.2.2 Softener 2 finishing		No water reuse
I06	B- Sized Flax-Pes fabric dyed with dark colours	F.3.2 Desizing & Scouring	Ultrafiltration and Nanofiltration	Reuse only discharge water and filling discharge water
		G.3.1 Dyeing PES	Ultrafiltration and Nanofiltration	Reuse only discharge water
		G.8.1 Dyeing Flax		No reuse of water because its high conductivity
		H.4 Antistatic Finishing		No water reuse
I09	A – silk yarn dyed with dark colours	F.1.3 HT scouring	Ultrafiltration and Nanofiltration	Reuse only discharge washing water
		G.6.2 Silk dark acid dyeing	Ultrafiltration and Nanofiltration	Reuse only discharge washing water
		H.1.1 Softener finishing		No water reuse
I15	A	F.1.1 Silk continuous scouring	Ultrafiltration and Nanofiltration	Reuse only rinsing water
		G.3.1 Silk dark acid dyeing	Ultrafiltration and Nanofiltration	Reuse only continuous washing water
B05	A	Bleaching		No water reuse
		Mercerising		No water reuse
		Vat dyes	Ultrafiltration and Nanofiltration	Reuse only rinsing water

Table 3.1.1 Selection o water management scenarios

3.2 LCA results for the " Innovative scenarios"

Innovative scenario ultrafiltration + nanofiltration was used to treat effluent of the selected product in I04, I06, I09, I15, B05 companies. The results are very good for I04 and I15 companies with water saving of 53% and 54%; in the other cases the saving was in the range 10%-35% (figure 3.2.1).

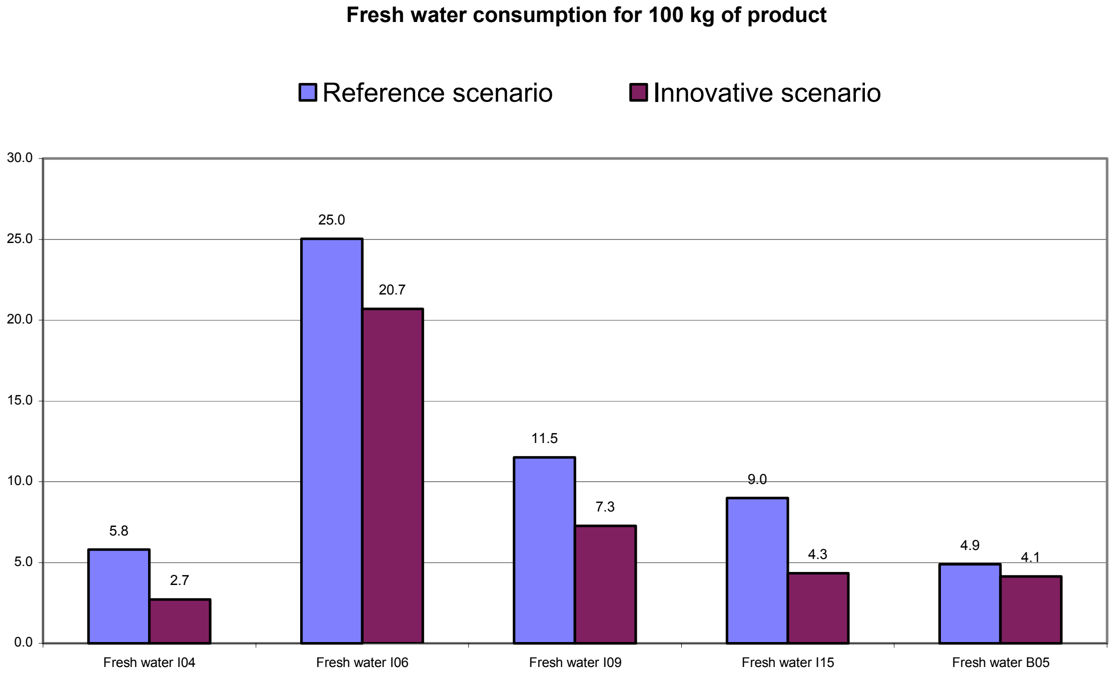

Figure 3.2.1 Fresh water consumption in reference and innovative scenario.

This water saving can be obtained with almost no additional load in the other main impact categories: the calculated impacts rise less than 1%. The determinant of these impacts is the electricity energy consumption for the membrane treatment plant; the absolute value of the increment is very low (range between 24 - 34 MJ per 100 kg of product). (Figure 3.2.2-3.2.6)

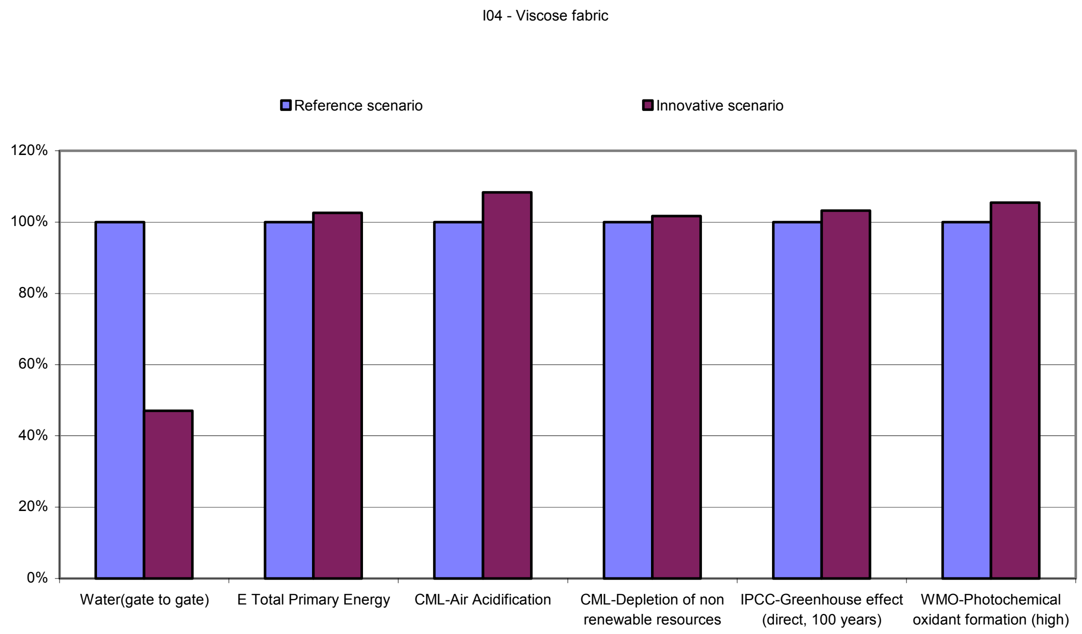

Figure 3.1.2 I04 reference and innovative scenarios.

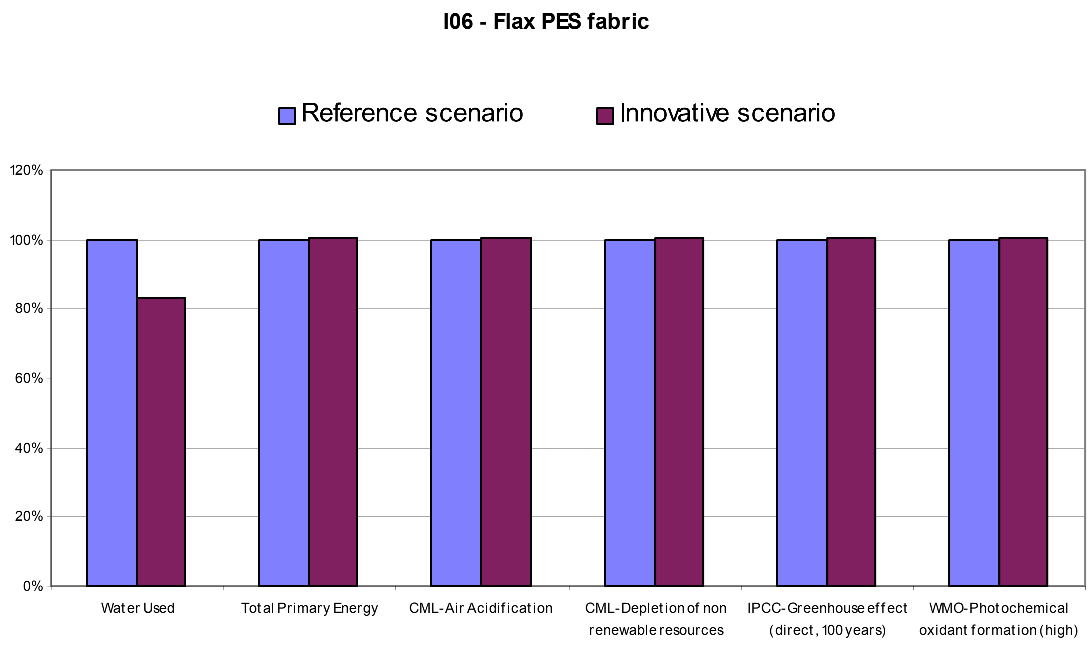

Figure 3.1.3 I06 reference and innovative scenarios.

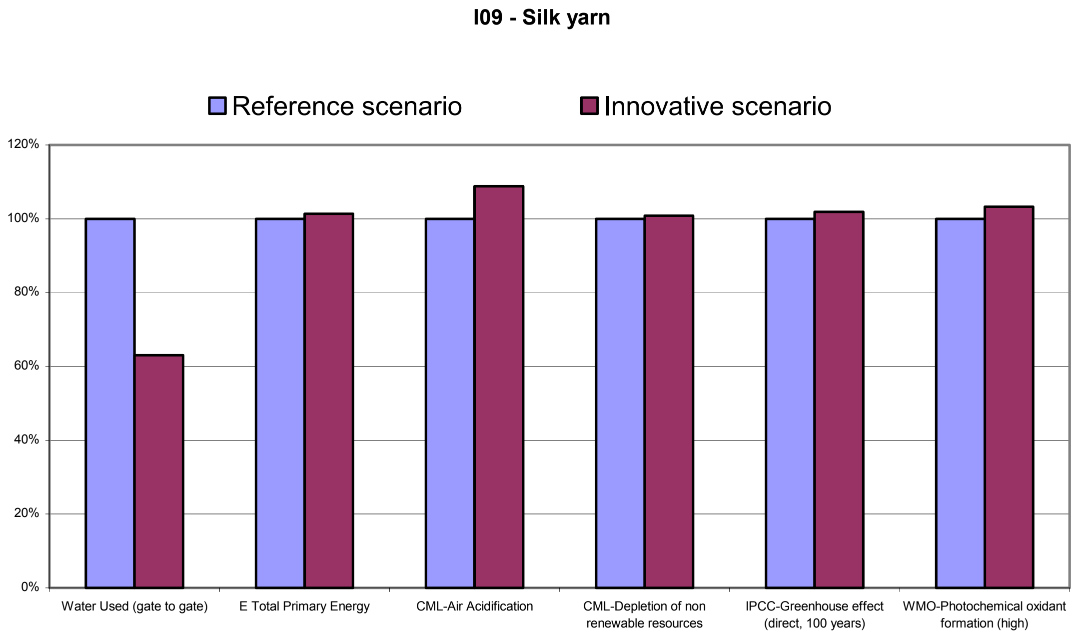

Figure 3.1.4 I09 reference and innovative scenarios.

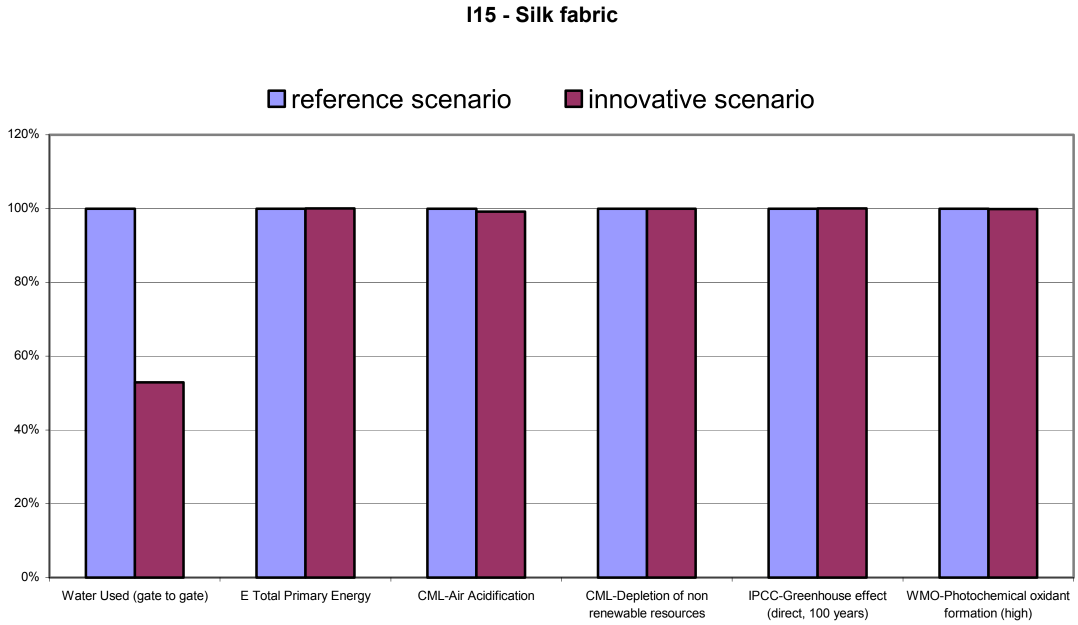

Figure 3.1.5 I15 reference and innovative scenarios.

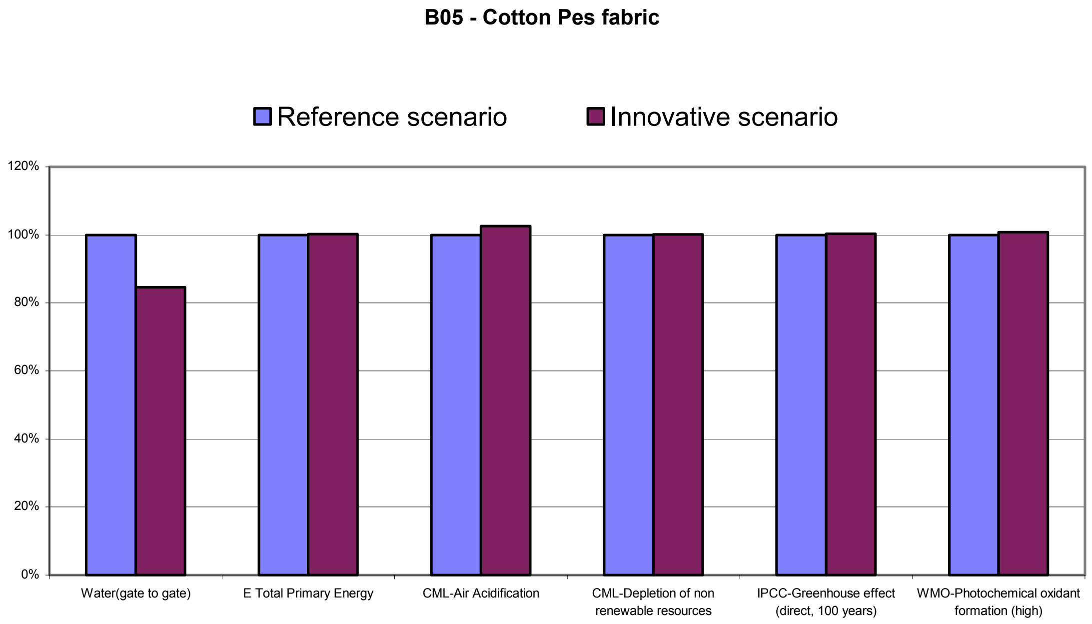

Figure 3.1.6 B05 reference and innovative scenarios.

3.3 *"Effluent zero scenario" results*

In the "Effluent zero scenario" ultrafiltration + reverse osmosis was used to treat effluents of viscose fabric processing in I02 company; for this effluents it was not possible to use ultrafiltration+ nanofiltration because of their high COD concentration. The potential water saving was estimated in 80% (Figure 3.3.1).

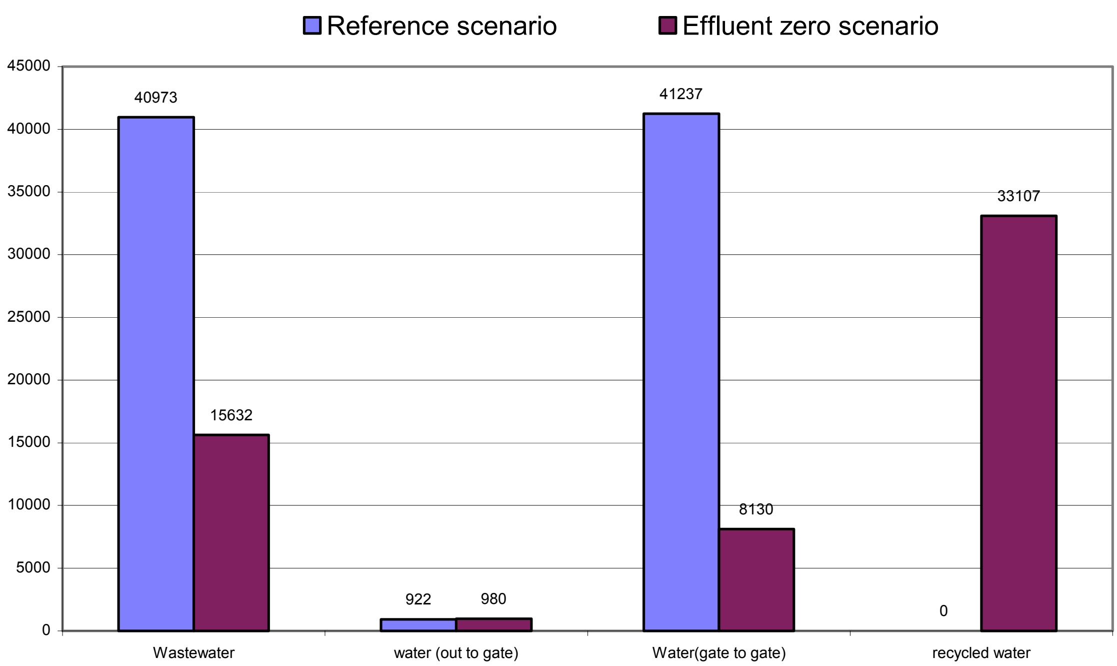

Figure 3.3.1 I02 water consumption for different scenarios.

The electricity use in reverse osmosis plant, not compensated by the energy savings to extract from wells and to pre-treat less water, caused a worsening of the energy indicators and of the “energy related” impact categories (figure 3.3.2)

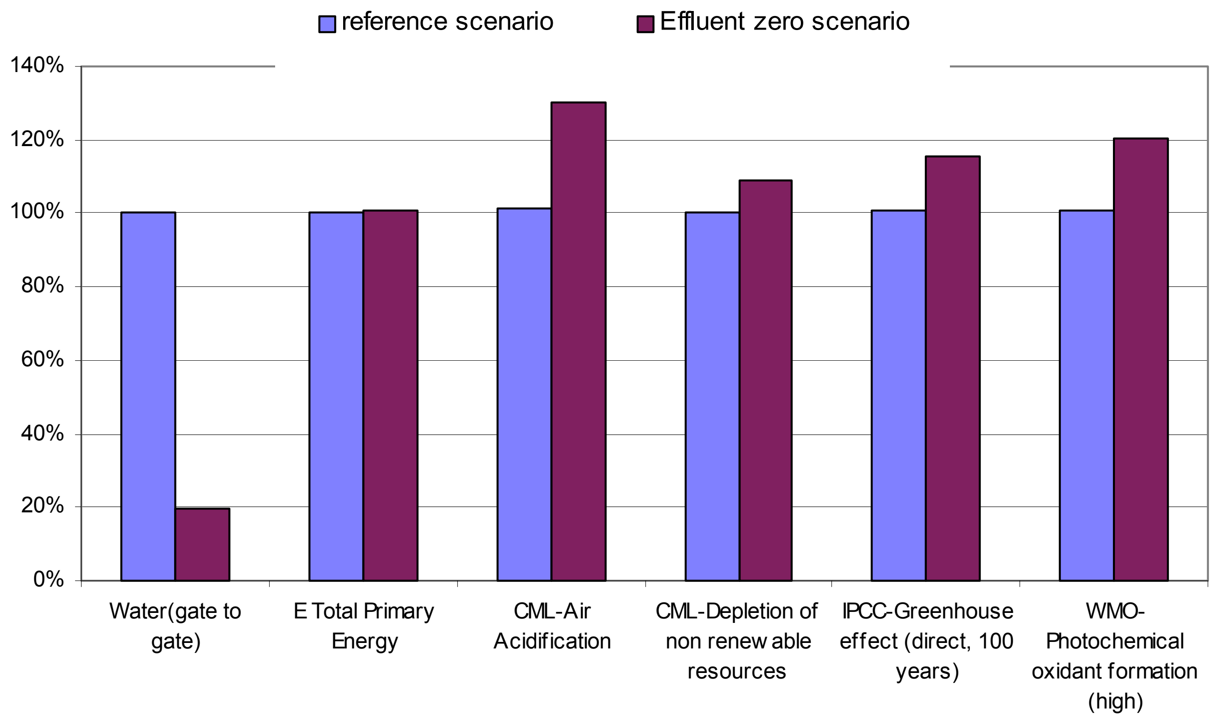

Figure 3.3.2 I02 “reference” and “effluent zero” scenarios

In this case the water saving should be weighted against the increment of the load in the other impact categories, taking in account the local environmental conditions and criticalities. The possibility to compensate for the increase of the electricity use adopting a more efficient energy policy in the company should be investigated too.

4 Conclusions

LCA methodology proved to be an useful tool for decision support in textile fnishing industrial sector. According to LCA results, the main determinants of the potential environmental impact are the water use and the combustion of fossil fuels for steam and electricity production. About the chemicals use should be underlined that, because lack of detailed chemical analyses on product specific effluents, it was not possible to take in account the toxicity effect of chemicals release to local water bodies. Anyway chemicals with specific environmental risk phrases R50, R51, R52, R54, R55, R56 and R57 have not been used in any Italian analysed product chain. With regard to water use, significant margins exist for impressive improvements with almost no additional environmental impact adopting ultrafiltration +nanofiltration membrane treatments on slightly polluted effluents. When using reverse osmosis membrane plants the expected load increase in “energy related” environmental impact categories should be evaluated in the local context together with the water savings.