TOWEF0

(Toward Effluent Zero)

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

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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 5th 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 characterized 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 center for the industry, Centexbel, a research center for the Belgian textile federation, the Joint research Centers 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 LCA methodology has been applied to selected Viscose-Fabric products within I02 company.

2 Goal and scope definition

2.1 *Goal of the study*

The main goal of this LCA study is to quantify the environmental performance of selected textile production processes within I02 company identifying the potential environmental critical points.
The results achieved in this study will be used to support the identification of environmental favorable technologies/strategies in textile finishing industries, to evaluate different wastewater management scenarios and to develop a database of inventory data of textile processes and chemicals to be used with a industry specific user friendly environmental assessment software to be developed by Ecobilan within the project Towef0.
This study has been performed according to the requirements of ISO 14040 standards by ENEA-PROT-INN LCA team. The study commissioner was the European Commission which funded the Towef0 project. Researchers and technicians working in textile sector were the intended target of this study.

2.2 *Scope of the study*

2.2.1 General description of the systems

I02 is an Italian company located in the Como area. Its annual production is over 415769 kg of fabric mainly made of viscose (27%), PES (20%), silk (17%), cotton (16%), silk/acetate (10%), wool (8%). The general organization of the company production departments is highlighted in the following material flowchart.

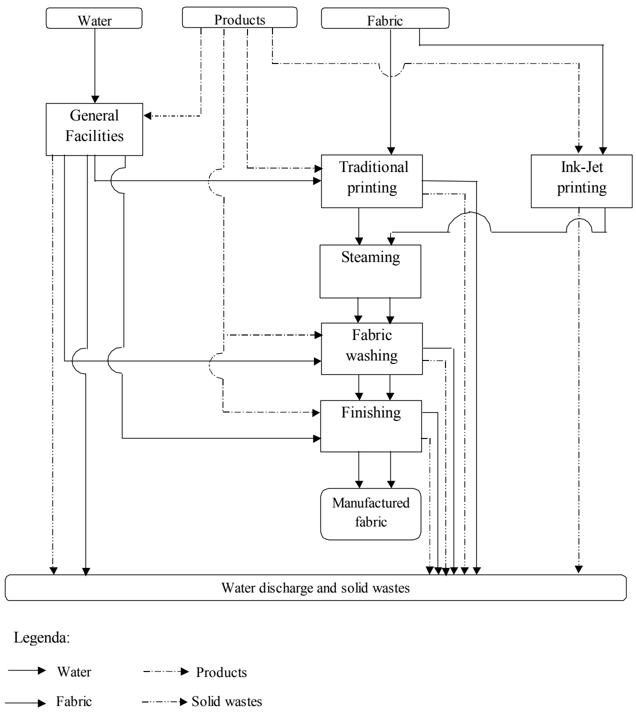

Fig. 2.1 Material flowchart of I02 company

A more detailed description of I02 company is available in Process Identification and data Collection Sheet (PIDACS) of I02 company.
In this study two viscose fabric product alternatives were analyzed:

- Electronic table reactive printing (System A);
- Rotary machine reactive printing (System B);

The two systems have the same general flow-chart and differs only for the printing process (Fig 2.2)

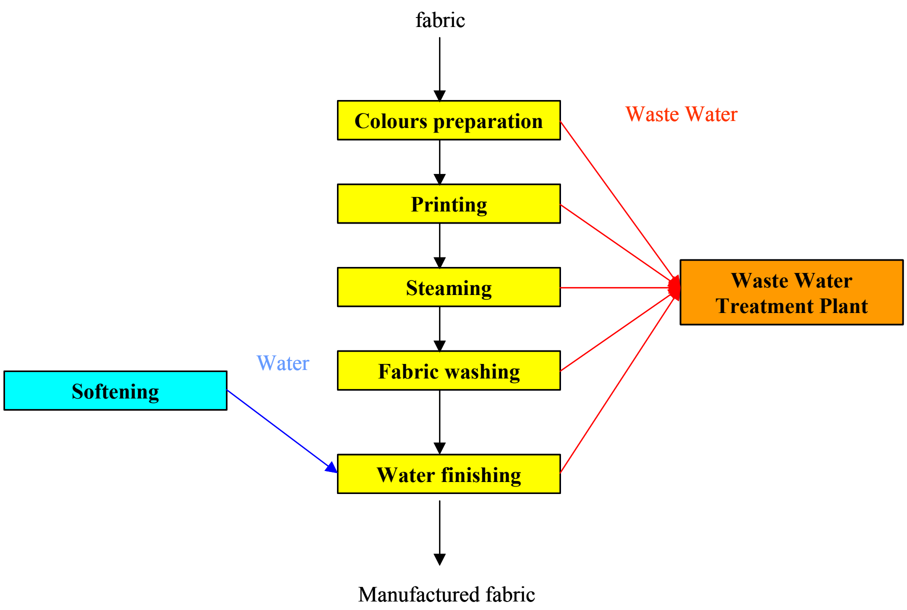

Fig.2.2 Schematic flowchart of analyzed viscose products.

Table 2.1 shows the textile wet processes of the two product systems; the processes numbers refer to I02 PIDACS classification.

Product systems	System A	System B
Colors preparation	F.1.1	F.1.1
Thickeners preparation	F.2.1	F.2.1
Printing paste preparation	F.3.1	F.3.1
Kids washing	F.10	F.10
Tubs washing	F.11	F.11
Printing	F.4.3	F.4.4
Printing screen washing	F.8	F.8
Printing squeegees washing	F.9	F.9
Steaming	G.1	G.1
Fabric washing	H.1.3	H.1.3
Water finishing	I.1	I.1

Table 2.1 Textile wet processes of the two product systems.

A typical printing process involves the following steps:

- Colour paste preparation: when printing textiles the dye or pigment is not in an aqueous liquor but is usually finely dispersed in a printing paste, in high concentration;
- Printing: the dye or pigment paste is applied to the substrate using different techniques;
- Fixation: immediately after printing, the fabric is dried and then the prints are fixed mainly with steam or hot air;
- After-treatment: this final operation consists in washing and drying the fabric.

For a better understanding of the report, a short description of the textile wet processes is presented hereafter. The descriptions are extracted from BREF or other relevant technical literature.

Printing paste preparation

The composition of the paste is more complex and variable, being determined not by the dye used, but by the printing technique, the substrate, the application and the fixation methods applied.

The printing paste contain thickeners agent and various other auxiliaries, which can be classified according to their function as follows:

- Oxidizing agents
- Reducing agent
- Substance with hydrotropic effect, like urea
- Dye solubilizer

All the necessary ingredients are metered and mixed together in a mixing station.

Printing

After preparation, the paste is applied to specific areas of the textile fabric using different machines. Flat screen and rotary screen machines are both characterized by the fact that the paste is transferred to the fabric trough openings in specially designed screens. Colour is forced trough the openings in each screen by means of a squeegee. A separate screen is made for each colour in the pattern. Flat screen printing machines can be manual, semi-automatic or completely automatic.

In the rotary-screen machine, the colour is transferred to the fabric through lightweight metal foil screens, which are made in the form of cylinder rollers.

The fabric moves along in continuous mode under a set of cylinder screens while at each position the print paste is automatically fed to the inside of the screen from a tank and is pressed through onto the fabric.

Steaming

After printing, the fabric is dried. Water evaporation leads to increase in the dye concentration and at the same time prevents the colors from smearing when the fabric is transported over guide rollers. At this stage the dye is not yet fixed.

Fixation is usually carried out with steam. Water vapour condenses on the printed material, swells up the thickeners, heats the print and provides the necessary transport medium for the diffusion of the dye.

The distribution of the dye between the fibre and thickener is an important factor in determining the fixation degree of the dye, which is called the “retaining power” of the thickener.

Washing
The last step of the printing process consist in washing and drying the fabric and in some kind of finishing .
When printing with insoluble dyes such as vat dyes this operation also serves as a means to re-convert the dye to the original oxidised state. In this case, after an initial rinsing with cold water, the printed material is treated with hydrogen peroxide. The process is completed with a soap treatment with sodium carbonate at the boiling point.

All these processes use water drawn from company wells. Only the water fed to the boiler is softened by means of ion exchange resins. The wastewater treatment for all the analyzed Italian companies is performed in a centralized WWTP which also treats municipal effluents.

A detailed description of the studied systems is available in chapter 3.2.
A general description of the equipment used for all textile processes is given in the Reference Document on Bat for Textile processing which can be downloaded from http://eippcb.jrc.es/pages/FActivities.htm.

2.2.2 System functions

The main functions of the studied systems are the printing, steaming, washing, finishing of viscose fabric including the relative colors preparation: The fabric is processed to reach the required commercial characteristics respecting the worker safety and the emissions limits according to the law in air, water and soil.

2.2.3 Functional unit and reference flow

The chosen functional unit is the printing, steaming, washing, finishing of a weight unit of viscose fabric, processed to reach the required commercial characteristics, respecting the worker safety and the emissions limits according to the law in air, water and soil.
The reference flow is 100 kg of viscose fabric.

2.2.4 System boundaries of product systems

The system boundaries of the two studied product alternatives are shown in Fig. 2.3. The processes included in the analysis are included in the system bold line.

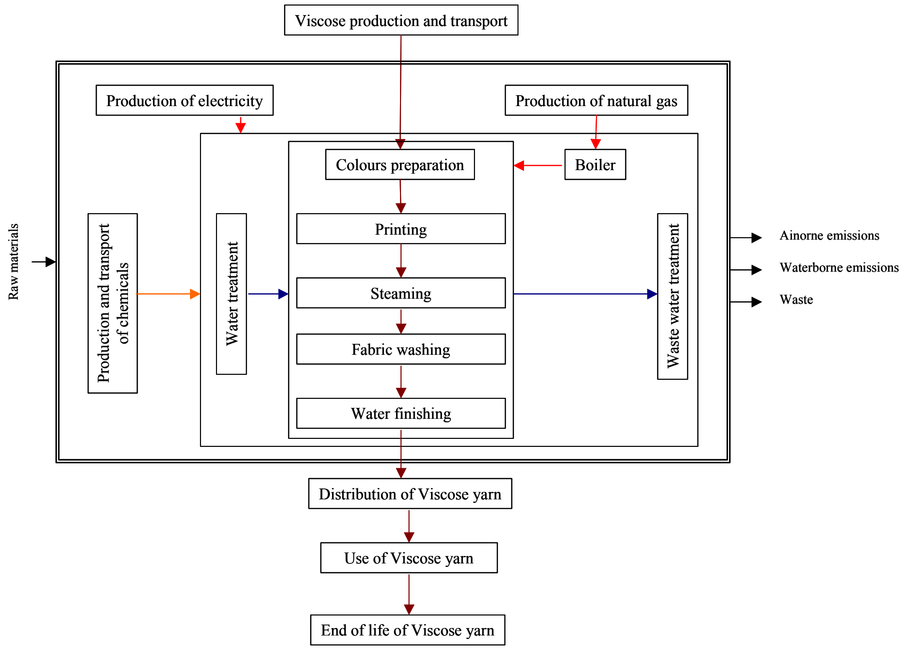

Fig 2.3 System boundaries of I02 product systems.

The processes excluded from the system boundaries are:

- viscose yarn and fabric production processes, including the relative transports;
- All the product life cycle phases external to the company gate;
- The production and manufacturing of all equipment, machinery and capital goods used in the industrial processes, as commonly accepted in LCA methodology.

2.2.5 Data categories

The choice of data categories has been made in relation to the impact categories and characterization factors adopted. They include the macro categories of energy, raw materials, chemicals and emissions in air water and soil.
Different data sources were used in this study:

Company specific data:

- Colors preparation
- Printing;
- Steaming;
- Washing;
- Finishing.

TEAM 3.0/Ecobilan data:

- production of electricity;
- production of methane;
- transport processes;
- boiler: general model which process parameters and efficiency are adjusted to I02 company;

Detailed hypotheses on the electricity production and on all the models used in this study are available in TEAM 3.0 modules database.

Lariana Depur data:

- All the centralized Waste Water Treatment Plant data.

Production of chemicals:
- TEAM 3.0/Ecobilan
- other LCA commercial databases and literature
- data collection from manufacturers;
- surrogate data (ETH) for performing sensitivity analyses and check the influence of the missed data.

2.2.6 Criteria for initial inclusion of inputs and outputs

All the inputs and outputs available in PIDACS were included in the study. Because of the large amount of base chemicals used for pre-treatment operation in textile wet processing, it was decided to include in the analysis the chemicals production. After a comprehensive review of the chemicals Life Cycle Inventories (LCI) available in commercial databases and direct contacts with the main textile chemicals manufacturers we included in the study the LCI data of 29% of the total chemicals mass used in the company processes. The influence of the missed data has been evaluated by sensitivity analyses.

2.2.7 Data quality requirements

The on site data gathered in this study have the following characteristics:
- Time related coverage: All the I02 data are related to year 2000;
- Geographical related coverage: the data are company specific and reflect the Como area situation;
- Technology coverage: The equipment used in I02 company are generally 15-20 years old. The technology level can be considered on average.

To model the two product systems several assumptions were necessary:

Main assumptions within the company boundary:

- Steam production

The annual company methane consumption as well as the annual steam consumption are metered and reported on the I02 PIDACS. The 95% of the methane is used for industrial processes described in the PIDACS, the remaining part is used for heating the factory shed (estimation of the company technicians). To evaluate the specific methane consumption for processes colors preparation, printing, steaming, washing, finishing, the specific consumption of steam has been calculated (m^3 of steam/m^3 of heated water* °C). The calculation took in account the volume of water to be heated up and the bath temperature and was based on the metered annual steam consumption. To calculate the emissions of methane burning and the natural resources consumption, the TEAM 3.0 model developed by Ecobilan was used, adjusting the water inlet and the steam outlet temperatures on the actual company data and calibrating the steam generator efficiency to meet 95% of the metered company methane consumption.

- Process specific wastewater effluent

The wastewater effluent from the company specific processes has been characterized only with measured COD and TSS concentration, due to unavailability of specific contaminant concentration.

- Number of washing cycles

Because the number of washing cycles of screens and squeegees can differ significantly depending on the number of colors used in the printing process, we assumed that for each printing cycle are used 8 colors, i.e. 8 screens (8 washing cycles)and 8 squeegees (4 washing cycles).

- Electricity consumption

The electricity consumption of specific processes has been calculated as [absorbed power] x [run time]. The electricity consumption for lighting and general services has been neglected, as generally accepted in LCA studies, because it is not relevant for the specific objectives of this study.

- Water pre-treatment

The potential impact of the production of the ionic exchange resins, as well as the water consumption for resins bed regeneration has been neglected, due to the very small quantities used. Only the potential impact of the salt production (used for resin regeneration) has been included in the study.

- Solid waste

The annual solid waste production of the company is specified in the PIDACS. The waste has been classified in three main fluxes: recycled waste (divided in packaging, iron and steel, plastic waste), special waste and special dangerous waste. The total waste quantity has been allocated to the analyzed product systems on a mass basis. The solid waste treatment has not been included in the systems, because of lack of specific data and the difficulty to identify reference treatment scenarios.

- Airborne emissions.

I02 PIDACS specifies for each emission source, typically a specific machinery, the chimney flow rate and the contaminants concentration. For LCA purposes the contaminants emissions in the environment have been calculated as: [emission source flow rate]x[machinery run time]x [contaminant concentration]. If the concentration has been indicated as < limit value, the specific limit value has been assumed.

Main assumptions for production of chemicals:
The inventories available in TEAM 3.0 database have been included in the study; the following databases were checked in addition to the TEAM 3.0 one:

- SimaPro;
- KCL Eco;
- IVAM;
- Boustead model;
- Specific industry data.

Main assumptions for Lariana WWTP:
We assumed that the potential environmental impacts of WWTP processes are mainly due to the production of the energy needed in the plant and to the emission of the treated effluent into the environment; the impact of chemicals production has been neglected. These hypotheses were based on results of previous LCA studies of ENEA.
The potential environmental impacts for treating the waste water of the studied product systems have been considered proportional to effluent mass.

Direct CO2 emissions in the environment from Lariana WWTP processes have not been considered (according to IPPC guidelines).
Because it was not possible to have information on the specific contaminants of the product systems water effluents, the evaluation of the potential impact connected to the release to the environment of the treated water effluent has been calculated considering the effluent mass of the specific analyzed processes and the contaminant concentration of the treated WWTP effluent.

2.2.8 Impact assessment methods

The impact assessment categories used for the analysis of the three product systems are indicated in table.2.2

CML 92-Air Acidification	Equivalent grams H+
CML 92-Aquatic Eco-toxicity	1000 m^3
CML 92-Depletion of non renewable resources	fraction of reserve
CML 92-Eutrophication	Equivalent grams PO4
CML 92-Human Toxicity	g
CML 92-Terrestrial Eco-toxicity	t
IPCC-Greenhouse effect (direct, 100 years)	Equivalent grams CO2
WMO-Photochemical oxidant formation (high)	Equivalent grams. ethylene
Reminders-Primary energy consumption	MJ

Tab. 2.2 Impact assessment categories

The chosen impact assessment categories are well know and accepted at international level: a short description can be found in TEAM software online documentation.
Because of project limits (detailed analyses of process wastewaters were not available) and methodological limits (characterization factors are available only for a small part of the manufactured chemicals), the EDIP (Environmental Design of Industrial Products method proposed by Wenzel and Haushild has been adopted for screening the potential impact of chemicals on ecotoxicity. A short description of the method is reported hereafter.
This EDIP screening method is based on the existing EU hazard classification of substances, available in the list of hazardous substances published by the EEC (1994). A semi-quantitative scoring of the substance in the inventory is obtained by calculating a score for exposure and a score for ecotoxicity, which are multiplied to give a final ecotoxicological impact score.
The idea behind multiplication of separate scores for exposure and ecotoxicity is that if emission of a substances is expected or if undesirable long term effects are possible, and the substance has some form of ecotoxicity, the score for environmental hazardousness will be increased significantly more than by simple addition. This is in agreement with a toxic property being assessed as having a greater environmental significance if the substance is emitted often, is not easily degradable or can undergo bioaccumulation.

Exposure score

The score for the exposure is a combination of expectation concerning emission (yes/no) and the possibility of undesiderable long term effects on the environment (R53 or R58) (not

readily biodegradable and/or potential for bioaccumulation or may cause long term adverse effects in the environment).
The two scores are added and their sum multiplied by the score for ecotoxicity.
R53 is a classification assigned to substances which are not easily biodegradable or which are potential bioaccumulators, and where the following values are found for acute toxicity:
96-hour LC_{50} (fish)$\leq$ 10 mg/l, or
48-hour EC_{50} (Daphnia))$\leq$ 10 mg/l, or
72-hour IC_{50} (algae) 10 mg/l.
There are no criteria for assignment of an R58 classification, which refers to undesirable long term effects in environments other than the aquatic environment.

Ecotoxicity score

The score of ecotoxic effects is a combination of ecotoxicity to aquatic organism (R50-R51-R52 alone or in combination with other R phrases) and ecotoxicity to soil-dwelling organism (R54-R55-R54 R56-R57 alone or in combination with other R phrases). The two scores are added to give a total score for the substance's ecotoxicity (see table 2.3)

Aquatic ecotoxicity		**Terrestrial ecotoxicity**	
(**R50**….) $LC_{50} \leq 1$ mg/l	**4**	R54 Toxic to flora or R55 Toxic to fauna or R56 Toxic to soil organisms or R57 **Toxic to bees**	**4**
(**R51**….) 1mg/l< $LC_{50} \leq 10$ mg/l	**2**		
(**R52**….) 10 mg/l< $LC_{50} \leq 100$ mg/l	**1**		

Tab. 2.3 Ecotoxicity scores

If no ecotoxicity data are available for the substance, it is assigned an ecotoxicity score of 8 (4 for water compartment and 4 for the soil compartment); if the substance is, however, well know and considered to have no significant hazardous effects, it is assigned a score of 0.

Ecotoxicological impact score

The total ecotoxicological impact score for the emissions calculated by multiplying the score for exposure and the score for ecotoxicity, for example:

	Ecotoxicity score 0	Ecotoxicity score 1	Ecotoxicity score 4	Ecotoxicity score 8
No emission and not classified as R53 or R58 (score 1)	0	1	4	8
Emission expected or R53 or R58 (score 4)	0	4	16	32
Emission expected and R53 or				

R58 (score 8)	0	8	32	64

Tab. 2.4 Impact assessment categories

2.2.9 Interpretation methods

In the interpretation phase of this study the potential environmental impact of the different processes has been evaluated, the significant issues have been identified and the contribution of the specific contaminant fluxes has been calculated.
The sensitivity check focused on allocation rules (thermal energy) and lack of inventory data for chemicals.
A comparison of the different product systems has been performed.

2.2.10 Critical review

Being a pilot study performed in a research project, this report has not been submitted to a critical review.

3 Inventory analysis

3.1 Procedures for data collection

Data were collected from I02 company with the Process Identification and data Collection Sheet (PIDACS) defined and used by the Towef0 project. The PIDACS contains information for the entire Towef0 project and a part of the data was extracted for the LCA study.
Flow-charts of the most representative production lines were identified on the basis of the PIDACS data.
Data collection was performed by Lariana Depur.
The elaboration of PIDACS data required further details concerning processes of I02 company. These information were obtained from Lariana Depur by phone and by e-mail contacts.

Data were implemented using predefined modules of the TEAM software. The modules were developed by Ecobilan and were specific for the textile finishing industrial sector.

The product system has been completed using modules of the TEAM database and other bibliographical sources.

3.2 Qualitative and quantitative description of unit processes

The next paragraphs describe data collected for the inventory analysis. Data elaboration procedures are explained and assumptions and allocation procedures are documented.

3.2.1 Viscose wet processing and general facilities

Annex 1 describes the general structure and content of the PIDACS.
As shown in Table 2.1, the most representative production lines of the studied products were identified in collaboration with Lariana Depur.

For each process of the selected production lines, the most productive equipment were identified. Table 3.1 summarizes the annual production of each process and the relative contribution of each equipment. On the basis of these data, some types of machinery were selected for the further inventory analysis:

M1-M2 for reactive colors preparation 40 kg fabric/run capacity;
M3-M4 for reactive colors thickener preparation: 100 kg fabric/run capacity;
ET1 for electronic table reactive printing: 285 kg fabric/run capacity;
RM1 for rotary machine reactive printing: 285 kg fabric/run capacity;
ST1 for saturated steaming: 1420 kg fabric/run capacity;
RW1 for acid printed washing: 19 kg fabric/run capacity;
R1 for water finishing: 572 kg fabric/run capacity.

Table 3.1: Selection of equipment on the basis of annual production.

	Colors preparation F.1.1	Tickeners preparation F.2.1	Printing paste preparation F.3.1	Kids washing F.10	Tubs washing F.11	Printing F.4.3	Printing F.4.4	Printing screen washing F.8	Printing sqeegees washing F.9	Steaming G.1	Fabric washing H.1.3	Water finishing I.1
annual production (ton)	179,662	179,662	179,662	-	-	81,512	82,750	-	-	333,167	13,216	187,097
Equipment												
M1	50%	-	-	-	-	-	-	-	-	-	-	-
M2	50%	-	-	-	-	-	-	-	-	-	-	-
M3	-	50%	-	-	-	-	-	-	-	-	-	-
M4	-	50%	-	-	-	-	-	-	-	-	-	-
Tubs	-	-	100%	-	-	-	-	-	-	-	-	-
KW1	-	-	-	100%	-	-	-	-	-	-	-	-
TW1	-	-	-	-	100%	-	-	-	-	-	-	-
ET1	-	-	-	-	-	50%	-	-	-	-	-	-
ET2	-	-	-	-	-	50%	-		-	-	-	-
RM1	-	-	-	-	-	-	100%	-	-	-	-	-
SCW1	-	-	-	-	-	-	-	100%	-	-	-	-
SQW1	-	-	-	-	-	-	-	-	100%	-	-	-
ST1	-	-	-	-	-	-	-	-	-	77%	-	-
ST2	-	-	-	-	-	-	-	-	-	23%	-	-
RW1	-	-	-	-	-	-	-	-	-	-	100%	-
R1	-	-	-	-	-	-	-	-	-	-	-	100%

Specific data about selected equipment and related processes were extracted from PIDACS. Moreover, data concerning general facilities were analyzed, too. These processes are:

- Ion exchange softening of water: **6380 m^3 water/year** capacity;
- Steam production: **2918 ton steam/year** capacity.

The next paragraphs describe the data available in PIDACS, their elaboration and the main assumptions necessary for the LCA study. Data are always related to the above described capacities of the selected equipment.

3.2.1.1 Water use

Table 3.2 shows the water consumption of the selected processes and equipment .

Table 3.2 Process specific water consumption.

	Water consumption (l/run x h)	Water consumption (m^3/year)
Colors preparation F.1.1		
Mixing	16	36
Washing	40	90
Total	56	126
Thickeners preparation F.2.1		
Mixing	200	180
Washing	400	360
total	600	540
Kids washing F.10		
Washing	700	84
Rinsing	700	84
total	1400	168
Tubs washing F.11		
Washing (2 tubs)	480	7459
total	480	7459
Printing F.4.3		
Table continuous washing	2200	2361
total	2200	2361
Printing F.4.4		
Table and cylinders continuous washing	2200	2396
total	2200	2396
Printing screen washing F.8		
Washing (1 screen)	450	19136
total	450	19136
Printing squeegees washing F.9		
Washing (2 squeegees)	450	4784
total	450	4784
Steaming G.1		
Steaming	925	167
total	925	167
Fabric washing H.1.3		
1st bath	1000	696
1st washing	1000	696
2nd bath	1000	696
2nd washing	1000	696
filling	1000	696
total	5000	3480
Water finishing I.1		
Doping, wringing , thermosetting	143	187
total	143	187

Water consumption of general facilities was neglected because of its irrelevant contribution to the total of category.

3.2.1.2 Electricity consumption

Table 3.3 describes the electricity consumption of each process.

Table 3.3 Consumption of electricity

	absorbed power (kW)	run time (h)	electricity (kWh/run)	number of run /year	working hours/year	electricity (kWh/year)
Colors preparation F.1.1	2,7	0,17	0,46	2253	376	1015
Thickeners preparation F.2.1	4,9	0,42	2,1	900	375	1838
Kids washing F.10	-	1,5	-	120	-	-
Tubs washing F.11 (2 tubs)	2,7	0,75	2,03	15539	11654	31466
Printing F.4.3	9	7,5	68	143	1073	9657
Printing F.4.4	9	3,8	34,2	290	1089	9801
Printing screen washing F.8 (1 screen)	4,95	0,17	0,84	42524	7229	35784
Printing squeegees washing F.9 (2 squeegees)	4,95	0,17	0,84	10631	1807	8945
Steaming G.1	19,8	11,54	229	180	2077	41125
Fabric washing H.1.3	9	1	9	696	696	6264
Water finishing I.1	29,7	4	119	328	1312	38966

Electricity consumption of boiler for steam production has not been considered because these values are included in the TEAM steam generator model.

3.2.1.3 Methane consumption

Methane is consumed for steam production. 95% of it is used for heating water of industrial processes described in PIDACS. 5% is used for heating the factory shed (estimation of the company technicians).

There were no process specific data concerning steam consumption. PIDACS contains information about annual methane and steam consumption. Allocation to specific processes of annual steam and methane was made by energy calculated with the next formula:

"required heating energy"[kJ] = volume of heated water [m^3] x (bath temperature – initial water temperature) [°C] x density of water [kg/m^3] x specific heat of water [kJ/kg x °C]

where:

- initial water temperature = 25 °C
- density of water = 1 kg/ m^3
- specific heat of water = 4,186 kJ/kg x °C

The value of "required heating energy" was calculated for each equipment of the I02 company and total methane consumption was allocated on the basis of the factor "total methane/total "required heating energy".

Table 3.4 shows the annual consumption of methane and steam, and the factors used for allocation.

Table 3.5 describes the calculation procedure for methane and steam consumption of processes of the selected production lines.

Table 3.4 Methane and steam production

	Unit	**Value**	**Comment**
methane consumption of I02	m^3/yr	1421000	
methane consumption for bath heating	m^3/yr	1349950	95% of methane consumption in I02
total “required heating energy”	kJ/yr	5468201	
factor “total methane/total “required heating energy”	m^3 /kJ	0,25	
steam consumption	kg/year	2918000	
factor “steam/methane”	kg/m^3	2,162	

Table 3.5 Calculation of steam consumption.

	Heated water	**Bath temperature**	**Required heating energy**	**Specific consumption of methane**	**Specific consumption of steam**	**Total specific consumption of steam /year**	**Number of run/year**	**Specific consumption of steam**
	(m^3/year)	**(°C)**	**kJ/bath**	**(m^3/yr)**	**(kg /yr)**	**(kg /yr)**	**(1/year)**	**(kg /run)**
Steaming G.1								
steaming								**9232**
total								**9232**
Washing H.1.3								
1st bath	557	30	13	695	1501			
2nd bath	557	40	21	1123	2426			
total						3927	696	**6**

3.2.1.4 Consumption of chemicals

Table 3.6 shows the concentration of chemicals used for each process. The mass of chemicals are calculated based on the volume of consumed water (see Chapter 3.1.1.1) or treated fabric (when concentration is defined in kg of chemicals/100 kg yarn [%]).

Table 3.6 Concentration of chemicals

	Solubilizing agent (450AA)	Thickening agent (482AA)	Reactive colors	Thickening agent (539AA)	Thickening agent (478AA)	Soaping agent (645AL)	Antifoaming agent (613AL)
	g/l	g/l	g/l	g/l	g/l	g/l	g/l
Colors preparation F.1.1							
Mixing	1000	400	2600				
Tickeners preparation F.2.1							
Mixing	15000	15000		5000	15000		
Fabric washing H.1.3							
1st bath						1	
2nd bath						1	0,5

Chemicals used for steam production have not been considered because general data on chemicals and materials consumption are included in the TEAM 3.0 model developed by Ecobilan.

3.2.1.5 Discharged water

Table 3.7 shows the COD and TSS concentrations of discharged water. Masses of total COD and TSS were calculated by multiplying the concentration values and the consumed water at each process step (see Chapter 3.1.1.1).

Table 3.7 Discharged water.

	COD (mg/l)	TSS (mg/l)
Colors preparation F.1.1		
washing	12000	2500
Thickeners preparation F.2.1		
washing	12000	2500
Kids washing F.10		
washing	4107	2125
rinsing	1127	33
Tubs washing F.11 (2 tubs)		
washing	3500	690
Printing F.4.3		
table continuos washing	2750	270
Printing F.4.4		
table and cylinders continuos washing	903	10
Printing screen washing F.8 (1 screen)		
washing	1050	406
Printing squeegees washing F.9 (2 squeegees)		
washing	389	947
Fabric washing H.1.3		
1st bath	398	271
1st washing	247	89
2nd bath	73	43
2nd washing	50	33
Water finishing I.1		
Doping, wringing, thermosetting	350	50

COD and TSS of general facilities were neglected because of their low values.

3.2.1.6 Airborne emission

PIDACS specifies for each emission source, typically a specific machinery, the chimney flow rate and the contaminants concentration. Contaminants emissions in the environment can be calculated as: [emission source flow rate] x [machinery run time] x [contaminant concentration].

Emission source	Run time (h)	Flow rate (Nm^3/h)	VOC [mg/Nm^3]	Aldehydes [mg/Nm^3]	Ammonia [mg/Nm^3]	NO_x [mg/Nm^3]	Particles [mg/Nm^3]	Contaminant emission [g]
ET1 Printing F.4.3	7,5	10820	1	-	-	-	-	**81,150**
ST1 Steaming G.1	11,54	2225	-	-	6,09	-	-	**156,369**
			23,6	-	-	-	-	**605,965**
			-	-	-	-	23,1	**593,127**
			-	0,67	-	-	-	**17,203**
RW1 Fabric washing H.1.3	1	4170	-	0,5	-	-	-	**2,085**
			0,1	-	-	-	-	**0,417**
			-	-	0,62	-	-	**2,585**
			-	-	-	-	0,13	**0,542**
R1 Water finishing I.1	4	10404	-	-	-	4	-	**166,464**
			-	0,5	-	-	-	**20,808**
			0,1	-	-	-	-	**4,162**
			-	-	1,93	-	-	**80,318**
			-	-	-	-	0,1	**4,161**

3.2.1.7 Solid waste

The annual solid waste production of the company is specified in the PIDACS. The total waste quantity has been allocated to the reference flow of the analyzed product systems on a mass basis. Table 3.8 describes annual and calculated values.

Table 3.8 Production of waste

	annual production (kg)	normalised to reference flow (kg)	destination of waste
I02 production	415769	100	
150203 Packing, rags, protection clothes	34160	8,22	incinerator
150102 Plastic package	1850	0,44	reuse
170405 Iron and steel	7190	1,73	reuse
190806 Ionic exchange exhaust resin	1400	0,34	recovery
080308 Wastes containing printing inks	8	0,002	incinerator

3.2.1.8 Production and transport of chemicals

Data about the production of chemicals were collected by a comprehensive review of the chemicals Life Cycle Inventories (LCI) available in commercial databases and software (TEAM 3.0, SimaPro 5, GaBi 3, IVAM, Boustead Model, KCL Eco) and by direct contacts with the main textile chemicals manufacturers.

In case of lack of data, production of chemicals was excluded from the product system. Chemicals were treated as flows and characterized in the impact assessment by means of EDIP method (see paragraph 2.2.8).
In the Interpretation phase of the LCA study, a sensitivity check was made on the lack of data about production of chemicals. Surrogate inventory data about the production of organic and inorganic chemicals (ETH) were applied to evaluate the sensitivity of the product system (see Chapter 5.2.2.2).
Table 3.9 summarizes the information on the used chemicals; table 3.10 highlights the sources of the inventory data on chemicals production included in the study.

Table 3.9 Chemicals

Process	**Code**	**Commercial Name**	**Chemical class**	**Supplier**
Colors preparation F.1.1				
	450AA	Urea	Solubilizing agent	C.P.L Prodotti chimici s.r.l
	482AA	Antioxidol S B R	Anti oxidizing agent	Nearchimica spa
Tickeners preparation F.2.1				
	450AA	Urea	Solubilizing agent	C.P.L Prodotti chimici s.r.l
	539AA	Prisulon HTL	Tickening agent	CHT
	478AA	Polyprint LB 610	Tickening agent	
	482AA	Antioxidol S B R	Anti oxidizing agent	Nearchimica spa
Fabric washing H.1.3				
	654AL	Lavaret LY	Soaping agent	Rel.Co.Srl
	613AL	Antifoam T125 (T1000)	Antifoaming agent	Eigenmann & Veronelli spa

Tab 3.10 Chemicals inventories included in the study.

Process		**kg/f.u**	**weight %**	**chemical classes**	**Source**
F1.1	reactive colors preparation	1,72	2%	Reactive dyestuff	CIBA
		0,66	1%	Solubilizing agent	
F2.1	reactive colors thickener preparation	19,81	24%	Solubilizing agent	TEAM
		19,81	24%	Thickening agent	
		19,81	24%	Anti oxidizing agent	
		6,6	8%	Thickening agent	
H1.3	acid printed washing	2,63	3%	Antifoaming agent	
		10,53	13%	Soaping agent	
E.1	softening	1,61	2%	NaCl	TEAM
	total	83,44			
	percentage of available chemicals		29%		

Transport of chemicals were considered on the basis of PIDACS data. Transport modules of the TEAM database were selected on the basis of type of freight. “Ton x km” values were calculated by multiplying transported mass and distance values. (see Table 3.10)

Table 3.11 Types and distances of transport of chemicals

Code	Chemical class	Supplier	Type of freight	Distance from delivery [km]
450AA	Solubilizing agent	C.P.L Prodotti chimici s.r.l	3,5 tons<Lorry<12 tons	<50
482AA	Anti oxidizing agent	Nearchimica spa	3,5 tons<Lorry<12 tons	<100
539AA	Tickening agent	CHT	3,5 tons<Lorry<12 tons	<100
478AA	Tickening agent	Information not available (n.a.)	3,5 tons<Lorry<12 tons	n.a.
654AL	Soaping agent	Rel.Co.Srl	3,5 tons<Lorry<12 tons	<50
613AL	Antifoaming agent	Eigenmann & Veronelli spa	3,5 tons<Lorry<12 tons	<100

3.2.2 Energy production

Modules of TEAM 3.0 were used for the production processes of electrical, thermal and mechanical energy.
To calculate the emissions of methane burning and the natural resources consumption of the boiler, the TEAM 3.0 model developed by Ecobilan was calibrated.
As Chapter 3.2.1.3 describes, the boiler of I02 company consumes 0,463 m^3 of methane for the production of 1 kg steam. This amount of consumed methane corresponds to 15,07 MJ of energy input calculated with the following assumptions:
density of the consumed methane: 0,72 kg/ m^3;
natural gas extracted from the environment for supplying 1 kg combustible gas: 1,13 kg;
natural gas extracted from the environment for supplying 1 MJ consumable energy by combustion (TEAM): 0,025 kg.
The model predefines some technical variables that influence methane consumption. Concerning I02 company, the next variables were modified:
Initial temperature of water: 90 ^oC
Final temperature of steam: 150 ^oC
Boiler yield: 0.175
These variables result the consumption of 15,07 MJ of energy/1 kg of steam.

3.2.3 Waste water treatment

We assumed that the potential environmental impacts of WWTP processes are mainly due to the production of the energy needed in the plant and to the emission of the treated effluent into the environment; the impact of chemicals production has been neglected. These hypotheses were based on the results of previous LCA studies of ENEA.
The potential environmental impacts for treating the waste water of the studied product systems have been considered proportional to effluent mass.
Direct CO_2 emissions to the environment from Lariana WWTP processes have not been considered (according to IPCC guidelines).
Because it was not possible to have information on the specific contaminants of the product systems water effluents, the evaluation of the potential impact connected to the release to the environment of the treated water effluent has been calculated considering the effluent mass of the specific product system and the contaminant concentration of the treated WWTP effluent.

Table 3.12 shows the data used to model WWTP.

Table 3.12 Data for modelling the WWTP

	Units	Value
Wastewater	litre/year	8.87E+09
Electricity	MJ/year	2.90E+07
Transport: Road (diesel oil, kg.km)	kg.km/year	8.99E+08
(w) Ammonia (NH4+, NH3, as N)	g/year	6.00E+07
(w) COD (Chemical Oxygen Demand)	g/year	5.19E+08
(w) Nitrates (NO3-)	g/year	7.89E+07
(w) Nitrites (NO2-)	g/year	1.77E+06
(w) Nitrogenous Matter (unspecified, as N)	g/year	1.40E+08

3.3 Results of inventory analysis

Tables 3-13 trough 3-14 show the inventories of system A and B. Only the main fluxes are showed (fluxes which sum reaches 99% contribution to the total of each environmental impact category).

Table 3.13 Results of inventory analysis of I02 electronic table reactive printing (only main flows are listed)

Flow	Units	Total	Printing	Washing	Steaming	Finishing	Softening	WWTP	Electricity WWTP
INPUT									
(r) Iron (Fe, ore)	kg	5,20E-01	3,46E-02	8,25E-02	3,72E-01	1,13E-02	9,89E-05	0,00E+00	2,02E-02
(r) Natural Gas (in ground)	kg	1,09E+02	1,37E+01	1,49E+01	7,62E+01	1,40E+00	1,26E-02	0,00E+00	2,51E+00
(r) Oil (in ground)	kg	3,58E+01	1,40E+01	8,28E+00	3,40E+00	3,56E+00	1,12E-02	0,00E+00	6,38E+00
(r) Uranium (U, ore)	kg	2,77E-04	1,07E-04	2,32E-05	1,46E-04	1,24E-07	4,07E-07	0,00E+00	2,23E-07
Water: Public Network	litre	1,31E+02	1,31E+02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Water: Unspecified Origin	litre	7,89E+02	6,06E+02	5,06E+01	8,02E+01	1,76E+01	2,68E+00	0,00E+00	3,16E+01
Water: Well	litre	4,12E+04	1,48E+04	2,63E+04	0,00E+00	0,00E+00	1,00E+02	0,00E+00	0,00E+00
OUTPUT									
(a) Aldehyde (unspecified)	g	1,58E+01	2,76E-03	1,10E+01	1,21E+00	3,64E+00	2,29E-06	0,00E+00	1,61E-04
(a) Alkane (unspecified)	g	1,42E+01	1,49E+00	2,39E+00	9,03E+00	4,52E-01	2,66E-03	0,00E+00	8,11E-01
(a) Ammonia (NH3)	g	4,49E+01	6,17E+00	1,36E+01	1,10E+01	1,40E+01	6,92E-05	0,00E+00	8,52E-03
(a) Arsenic (As)	g	2,18E-02	7,49E-03	5,25E-03	2,84E-03	2,23E-03	1,29E-05	0,00E+00	3,99E-03
(a) Benzene (C6H6)	g	2,12E+00	2,53E-01	3,48E-01	1,34E+00	6,37E-02	7,02E-04	0,00E+00	1,14E-01
(a) Butane (n-C4H10)	g	8,44E+00	2,06E+00	1,74E+00	2,97E+00	5,90E-01	2,12E-03	0,00E+00	1,06E+00
(a) Cadmium (Cd)	g	4,44E-02	1,69E-02	1,05E-02	4,24E-03	4,54E-03	1,46E-05	0,00E+00	8,15E-03
(a) Carbon Dioxide (CO2, fossil)	g	4,07E+05	8,86E+04	6,86E+04	2,01E+05	1,71E+04	9,92E+01	0,00E+00	3,06E+04
(a) Ethane (C2H6)	g	5,60E+01	1,67E+01	1,25E+01	1,33E+01	4,80E+00	1,71E-02	0,00E+00	8,61E+00
(a) Ethylene (C2H4)	g	4,96E+01	2,24E+00	7,56E+00	3,77E+01	7,68E-01	8,61E-03	0,00E+00	1,38E+00
(a) Heptane (C7H16)	g	6,20E-01	2,29E-01	1,49E-01	6,07E-02	6,38E-02	2,01E-04	0,00E+00	1,14E-01
(a) Hexane (C6H14)	g	1,24E+00	4,58E-01	2,97E-01	1,22E-01	1,28E-01	4,02E-04	0,00E+00	2,29E-01
(a) Hydrocarbons (except methane)	g	3,67E+02	1,25E+02	6,59E+01	1,05E+02	2,54E+01	8,50E-02	0,00E+00	4,41E+01
(a) Hydrocarbons (unspecified)	g	7,12E-01	6,02E-01	3,62E-02	3,29E-02	1,44E-02	1,84E-04	0,00E+00	2,57E-02
(a) Lead (Pb)	g	1,08E-01	4,45E-02	2,30E-02	1,37E-02	9,64E-03	5,28E-05	0,00E+00	1,73E-02
(a) Methane (CH4)	g	1,66E+03	6,57E+02	3,27E+02	3,17E+02	1,28E+02	5,24E-01	0,00E+00	2,30E+02
(a) Nickel (Ni)	g	8,77E-01	3,36E-01	2,07E-01	8,39E-02	8,95E-02	2,88E-04	0,00E+00	1,60E-01

(a) Nitrogen Oxides (NOx as NO2)	g	5,12E+02	1,67E+02	9,10E+01	1,29E+02	6,07E+01	1,70E-01	0,00E+00	5,67E+01
(a) Propane (C3H8)	g	1,47E+01	4,20E+00	3,22E+00	3,87E+00	1,21E+00	4,76E-03	0,00E+00	2,17E+00
(a) Sulphur Oxides (SOx as SO2)	g	1,80E+03	6,76E+02	4,13E+02	2,14E+02	1,76E+02	6,88E-01	0,00E+00	3,15E+02
(a) Toluene (C6H5CH3)	g	1,25E+00	1,94E-01	2,28E-01	6,70E-01	5,69E-02	3,18E-04	0,00E+00	1,02E-01
(a) Vanadium (V)	g	3,39E+00	1,25E+00	8,22E-01	3,23E-01	3,57E-01	1,13E-03	0,00E+00	6,40E-01
(s) Arsenic (As)	g	8,16E-04	3,23E-05	1,23E-04	6,30E-04	1,11E-05	1,02E-07	0,00E+00	1,99E-05
(s) Chromium (Cr III, Cr VI)	g	1,06E-02	7,75E-04	1,53E-03	7,89E-03	1,39E-04	1,28E-06	0,00E+00	2,49E-04
(s) Copper (Cu)	g	1,66E-02	1,66E-02	2,82E-07	1,45E-06	2,55E-08	2,35E-10	0,00E+00	4,57E-08
(s) Zinc (Zn)	g	3,10E-02	1,52E-03	4,61E-03	2,37E-02	4,17E-04	3,84E-06	0,00E+00	7,48E-04
(w) Ammonia (NH4+, NH3, as N)	g	2,99E+02	2,12E+01	3,68E-01	1,85E-01	1,55E-01	6,63E-04	2,77E+02	2,77E-01
(w) Benzene (C6H6)	g	4,61E-01	1,64E-01	1,09E-01	5,80E-02	4,58E-02	1,46E-04	0,00E+00	8,20E-02
(w) Cadmium (Cd++)	g	1,43E-03	5,62E-04	3,02E-04	2,15E-04	1,22E-04	4,29E-07	0,00E+00	2,19E-04
(w) Chromium (Cr III)	g	2,15E-02	8,48E-04	3,22E-03	1,66E-02	2,92E-04	2,69E-06	0,00E+00	5,23E-04
(w) Chromium (Cr III, Cr VI)	g	1,99E-02	1,47E-02	1,98E-03	8,80E-04	8,44E-04	3,02E-06	0,00E+00	1,51E-03
(w) COD (Chemical Oxygen Demand)	g	2,41E+03	8,84E+00	5,79E-01	1,27E+00	1,72E-01	6,72E-04	2,40E+03	3,08E-01
(w) Nitrogenous Matter (unspecified, as N)	g	6,48E+02	6,98E-01	4,56E-01	1,99E-01	1,96E-01	6,18E-04	6,46E+02	3,52E-01
(w) Oils (unspecified)	g	6,72E+00	1,16E+00	1,23E+00	3,43E+00	3,17E-01	1,35E-03	0,00E+00	5,69E-01
Wastewater	litre	4,10E+04	1,46E+04	2,63E+04	0,00E+00	1,00E+02	0,00E+00	0,00E+00	0,00E+00
REMINDERS									
COD in peso	Kg	1,45E+01	1,11E+01	3,39E+00	0,00E+00	3,50E-02	0,00E+00	0,00E+00	0,00E+00
TSS in peso	Kg	4,41E+00	2,51E+00	1,89E+00	0,00E+00	5,00E-03	0,00E+00	0,00E+00	0,00E+00
E Feedstock Energy	MJ	1,43E+02	5,93E+01	2,86E+01	2,25E+01	1,16E+01	4,36E-02	0,00E+00	2,08E+01
E Fuel Energy	MJ	6,34E+03	1,26E+03	1,04E+03	3,37E+03	2,35E+02	1,51E+00	0,00E+00	4,21E+02
E Non Renewable Energy	MJ	6,26E+03	1,23E+03	1,02E+03	3,37E+03	2,27E+02	1,52E+00	0,00E+00	4,06E+02
E Renewable Energy	MJ	1,88E+02	5,88E+01	4,74E+01	2,52E+01	2,01E+01	2,67E-02	0,00E+00	3,61E+01
E Total Primary Energy	MJ	6,55E+03	1,39E+03	1,07E+03	3,40E+03	2,47E+02	1,55E+00	0,00E+00	4,42E+02
Electricity	MJ elec	8,05E+02	2,58E+02	1,98E+02	1,15E+02	8,35E+01	1,48E-01	1,34E+02	1,56E+01

Table 3.14 Results of inventory analysis of I02 rotary machine reactive printing (only main flows are listed)

Flow	Units	Total	Printing	Washing	Steaming	Finishing	Softening	WWTP	Electricity WWTP
INPUT									
(r) Iron (Fe, ore)	kg	5,15E-01	2,93E-02	8,25E-02	3,72E-01	1,13E-02	9,89E-05	0,00E+00	2,02E-02
(r) Natural Gas (in ground)	kg	1,08E+02	1,31E+01	1,49E+01	7,62E+01	1,40E+00	1,26E-02	0,00E+00	2,51E+00
(r) Oil (in ground)	kg	3,41E+01	1,23E+01	8,28E+00	3,40E+00	3,56E+00	1,12E-02	0,00E+00	6,38E+00
(r) Uranium (U, ore)	kg	2,77E-04	1,07E-04	2,32E-05	1,46E-04	1,24E-07	4,07E-07	0,00E+00	2,23E-07
Water: Public Network	litre	1,31E+02	1,31E+02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Water: Unspecified Origin	litre	7,81E+02	5,97E+02	5,06E+01	8,02E+01	1,76E+01	2,68E+00	0,00E+00	3,16E+01
Water: Well	litre	4,12E+04	1,48E+04	2,63E+04	0,00E+00	0,00E+00	1,00E+02	0,00E+00	0,00E+00
OUTPUT									
(a) Aldehyde (unspecified)	g	1,58E+01	2,71E-03	1,10E+01	1,21E+00	3,64E+00	2,29E-06	0,00E+00	1,61E-04
(a) Alkane (unspecified)	g	1,40E+01	1,28E+00	2,39E+00	9,03E+00	4,52E-01	2,66E-03	0,00E+00	8,11E-01
(a) Ammonia (NH3)	g	4,49E+01	6,17E+00	1,36E+01	1,10E+01	1,40E+01	6,92E-05	0,00E+00	8,52E-03
(a) Arsenic (As)	g	2,08E-02	6,44E-03	5,25E-03	2,84E-03	2,23E-03	1,29E-05	0,00E+00	3,99E-03
(a) Benzene (C6H6)	g	2,09E+00	2,22E-01	3,48E-01	1,34E+00	6,37E-02	7,02E-04	0,00E+00	1,14E-01
(a) Butane (n-C4H10)	g	8,16E+00	1,78E+00	1,74E+00	2,97E+00	5,90E-01	2,12E-03	0,00E+00	1,06E+00
(a) Cadmium (Cd)	g	4,22E-02	1,48E-02	1,05E-02	4,24E-03	4,54E-03	1,46E-05	0,00E+00	8,15E-03
(a) Carbon Dioxide (CO2, fossil)	g	3,99E+05	8,05E+04	6,86E+04	2,01E+05	1,71E+04	9,92E+01	0,00E+00	3,06E+04
(a) Ethane (C2H6)	g	5,37E+01	1,45E+01	1,25E+01	1,33E+01	4,80E+00	1,71E-02	0,00E+00	8,61E+00
(a) Ethylene (C2H4)	g	4,93E+01	1,87E+00	7,56E+00	3,77E+01	7,68E-01	8,61E-03	0,00E+00	1,38E+00
(a) Heptane (C7H16)	g	5,90E-01	1,99E-01	1,49E-01	6,07E-02	6,38E-02	2,01E-04	0,00E+00	1,14E-01
(a) Hexane (C6H14)	g	1,18E+00	3,97E-01	2,97E-01	1,22E-01	1,28E-01	4,02E-04	0,00E+00	2,29E-01
(a) Hydrocarbons (except methane)	g	3,27E+02	8,45E+01	6,59E+01	1,05E+02	2,54E+01	8,50E-02	0,00E+00	4,41E+01
(a) Hydrocarbons (unspecified)	g	7,05E-01	5,96E-01	3,62E-02	3,29E-02	1,44E-02	1,84E-04	0,00E+00	2,57E-02
(a) Lead (Pb)	g	1,04E-01	3,99E-02	2,30E-02	1,37E-02	9,64E-03	5,28E-05	0,00E+00	1,73E-02
(a) Methane (CH4)	g	1,60E+03	5,96E+02	3,27E+02	3,17E+02	1,28E+02	5,24E-01	0,00E+00	2,30E+02
(a) Nickel (Ni)	g	8,35E-01	2,94E-01	2,07E-01	8,39E-02	8,95E-02	2,88E-04	0,00E+00	1,60E-01
(a) Nitrogen Oxides (NOx as NO2)	g	4,97E+02	1,52E+02	9,10E+01	1,29E+02	6,07E+01	1,70E-01	0,00E+00	5,67E+01

(a) Propane (C3H8)	g	1,41E+01	3,63E+00	3,22E+00	3,87E+00	1,21E+00	4,76E-03	0,00E+00	2,17E+00
(a) Sulphur Oxides (SOx as SO2)	g	1,71E+03	5,93E+02	4,13E+02	2,14E+02	1,76E+02	6,88E-01	0,00E+00	3,15E+02
(a) Toluene (C6H5CH3)	g	1,23E+00	1,67E-01	2,28E-01	6,70E-01	5,69E-02	3,18E-04	0,00E+00	1,02E-01
(a) Vanadium (V)	g	3,22E+00	1,08E+00	8,22E-01	3,23E-01	3,57E-01	1,13E-03	0,00E+00	6,40E-01
(s) Arsenic (As)	g	8,11E-04	2,70E-05	1,23E-04	6,30E-04	1,11E-05	1,02E-07	0,00E+00	1,99E-05
(s) Chromium (Cr III, Cr VI)	g	1,05E-02	7,10E-04	1,53E-03	7,89E-03	1,39E-04	1,28E-06	0,00E+00	2,49E-04
(s) Copper (Cu)	g	1,66E-02	1,66E-02	2,82E-07	1,45E-06	2,55E-08	2,35E-10	0,00E+00	4,57E-08
(s) Zinc (Zn)	g	3,08E-02	1,32E-03	4,61E-03	2,37E-02	4,17E-04	3,84E-06	0,00E+00	7,48E-04
(w) Ammonia (NH4+, NH3, as N)	g	2,99E+02	2,11E+01	3,68E-01	1,85E-01	1,55E-01	6,63E-04	2,77E+02	2,77E-01
(w) Benzene (C6H6)	g	4,39E-01	1,42E-01	1,09E-01	5,80E-02	4,58E-02	1,46E-04	0,00E+00	8,20E-02
(w) Cadmium (Cd++)	g	1,38E-03	5,04E-04	3,02E-04	2,15E-04	1,22E-04	4,29E-07	0,00E+00	2,19E-04
(w) Chromium (Cr III, Cr VI)	g	1,95E-02	1,43E-02	1,98E-03	8,80E-04	8,44E-04	3,02E-06	0,00E+00	1,51E-03
(w) Chromium (Cr VI)	g	4,00E-07	1,33E-08	6,05E-08	3,11E-07	5,48E-09	5,04E-11	0,00E+00	9,83E-09
(w) COD (Chemical Oxygen Demand)	g	2,41E+03	8,76E+00	5,79E-01	1,27E+00	1,72E-01	6,72E-04	2,40E+03	3,08E-01
(w) Nitrogenous Matter (unspecified, as N)	g	6,48E+02	6,05E-01	4,56E-01	1,99E-01	1,96E-01	6,18E-04	6,46E+02	3,52E-01
(w) Oils (unspecified)	g	6,57E+00	1,01E+00	1,23E+00	3,43E+00	3,17E-01	1,35E-03	0,00E+00	5,69E-01
Wastewater	litre	0,00E+00	1,46E+04	2,63E+04	0,00E+00	1,00E+02	0,00E+00	0,00E+00	0,00E+00
REMINDERS									
COD in peso	Kg	1,42E+01	1,08E+01	3,39E+00	0,00E+00	3,50E-02	0,00E+00	0,00E+00	0,00E+00
TSS in peso	Kg	4,37E+00	2,47E+00	1,89E+00	0,00E+00	5,00E-03	0,00E+00	0,00E+00	0,00E+00
E Feedstock Energy	MJ	1,37E+02	5,38E+01	2,86E+01	2,25E+01	1,16E+01	4,36E-02	0,00E+00	2,08E+01
E Fuel Energy	MJ	6,23E+03	1,15E+03	1,04E+03	3,37E+03	2,35E+02	1,51E+00	0,00E+00	4,21E+02
E Non Renewable Energy	MJ	6,16E+03	1,12E+03	1,02E+03	3,37E+03	2,27E+02	1,52E+00	0,00E+00	4,06E+02
E Renewable Energy	MJ	1,78E+02	4,93E+01	4,74E+01	2,52E+01	2,01E+01	2,67E-02	0,00E+00	3,61E+01
E Total Primary Energy	MJ	6,44E+03	1,28E+03	1,07E+03	3,40E+03	2,47E+02	1,55E+00	0,00E+00	4,42E+02
Electricity	MJ elec	7,66E+02	2,19E+02	1,98E+02	1,15E+02	8,35E+01	1,48E-01	1,34E+02	1,56E+01

4 Life cycle impact assessment

Classification and characterization were done on the basis of the impact assessment methods selected during scope definition of the study (see Chapter 2.2.8).

5 Life cycle interpretation

5.1 Identification of significant issues and Contribution analysis for system A

In the following paragraphs the diagrams of the selected impact assessment categories and inventory data are presented for system A (electronic table reactive printing) to highlight significant issues. Contributions of electricity production, steam production and chemicals production, as well as the main contaminant flows are reported in tables for each impact category.

5.1.1 Water consumption

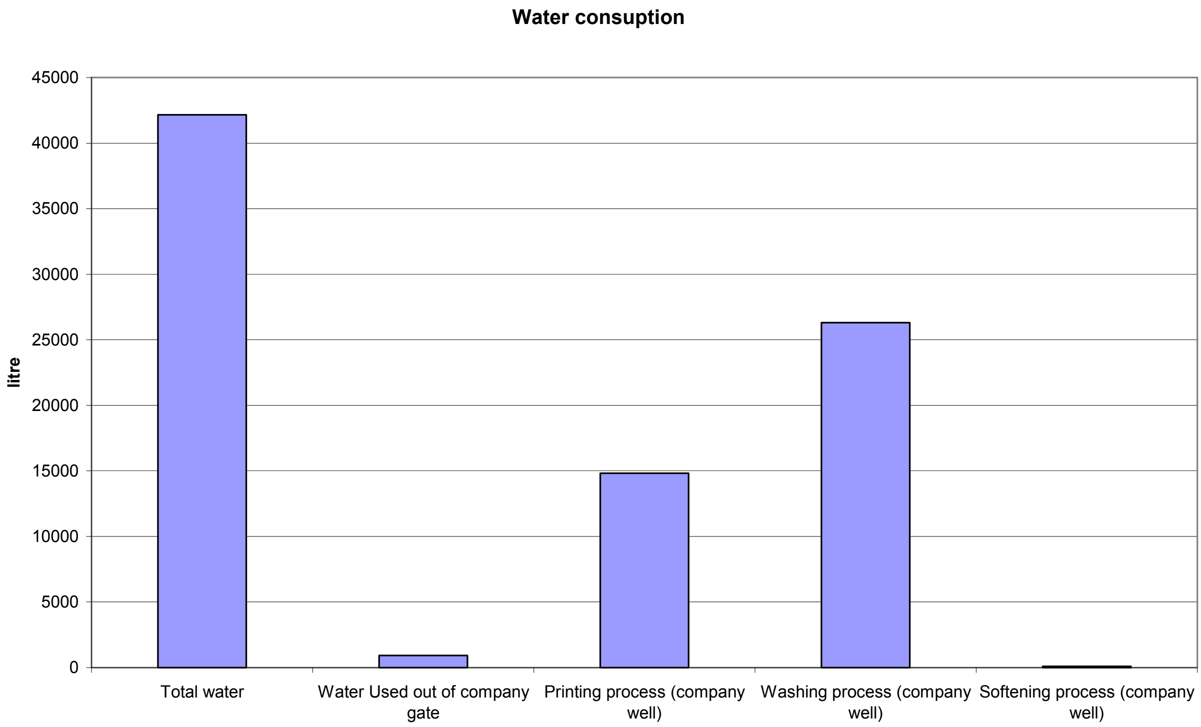

Fig. 5.1 Water consumption for the selected functional unit.

5.1.2 COD and TSS

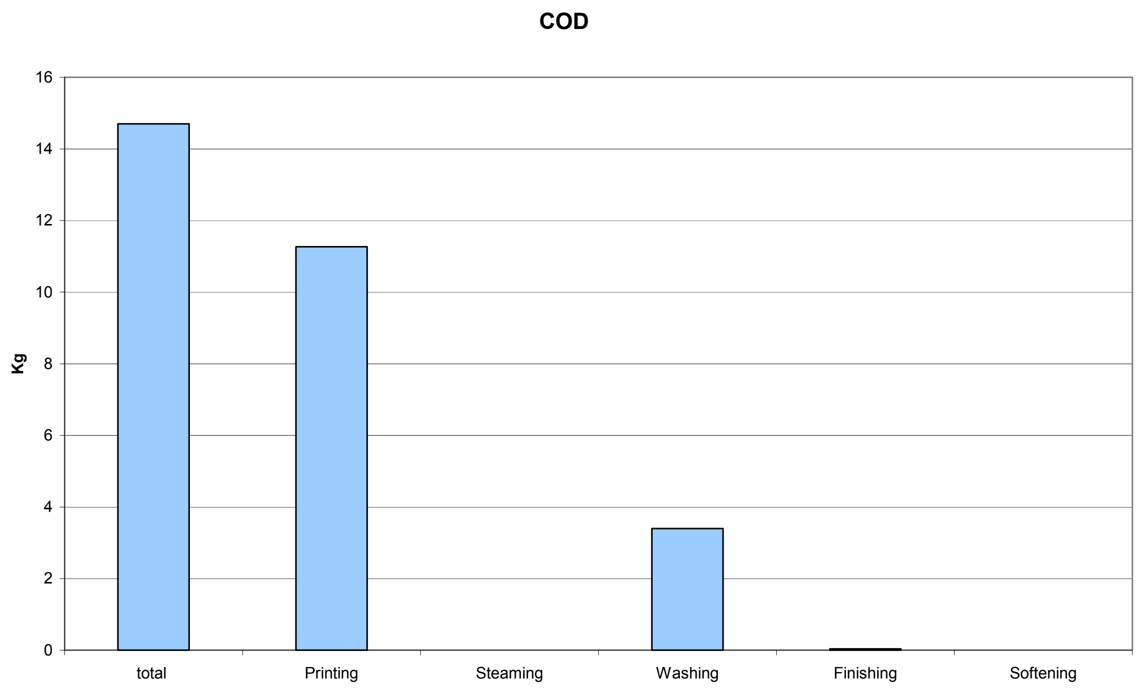

Fig. 5.2 COD emissions to WWTP for specific processes.

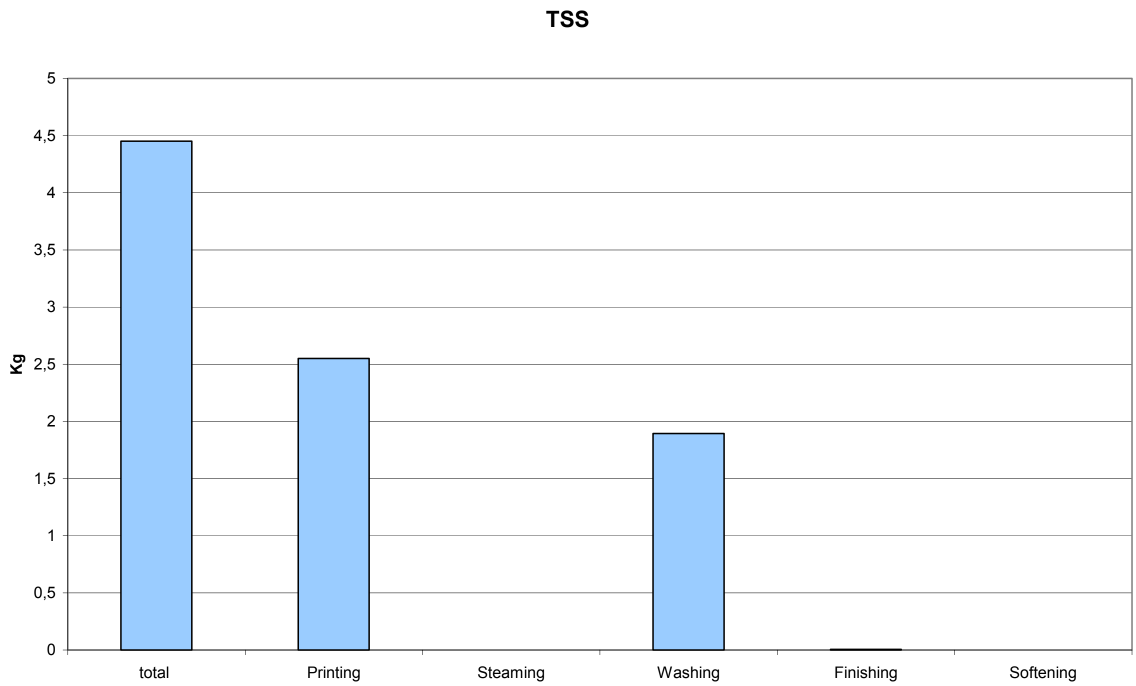

Fig. 5.3 TSS emissions to WWTP for specific processes

5.1.3 Energy indicators

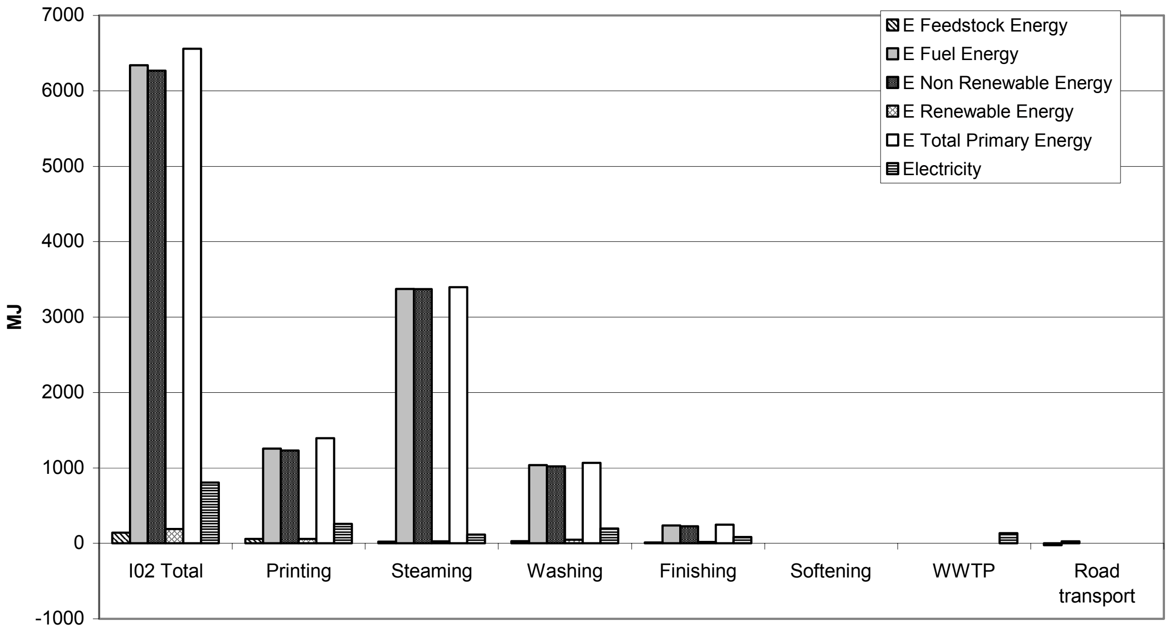

Fig. 5.4 Energy indicators.

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. It is an indicator of the efficiency of the use of energy natural resources in the overall system. Feedstock energy is the energy embodied in natural resources that are used as raw materials (not used as fuel) in the system.

Impact categories	*Units*	*Chemicals production*	*Steam production*	*Electricity production*	*Transport*	*WWTP*
E Total Primary Energy	**MJ**	10%	57%	33%	0%	0%

Table 5.1 Main contributors to the total of category.

5.1.4 Air Acidification

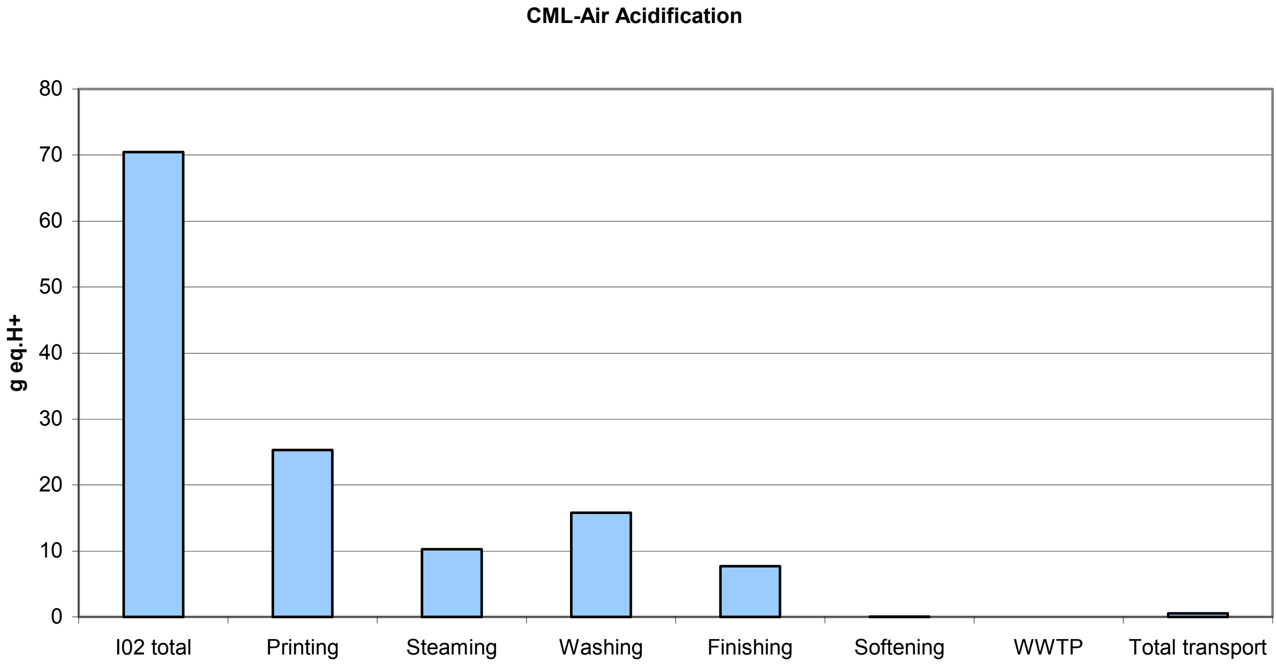

Fig. 5.5 CML 92 Air acidification.

Impact categories	***Units***	***Chemicals production***	***Steam production***	***Electricity production***	***Transport***	***WWTP***
CML-Air Acidification	**g eq. H+**	10%	8%	77%	1%	0%

Table 5.2 Main contributors to the total of category.

Impact assessment	**Unit**		**%**
CML-Air Acidification	g eq. H+	**70**	100%
(a) Sulphur Oxides (SOx as SO2)	g eq. H+	56	≅ 80%
(a) Nitrogen Oxides (NOx as NO2)	g eq. H+	11	≅ 16%
(a) Ammonia (NH3)	g eq. H+	3	≅ 4%

Table 5.3 Main contaminant fluxes.

5.1.5 Depletion of non renewable resources

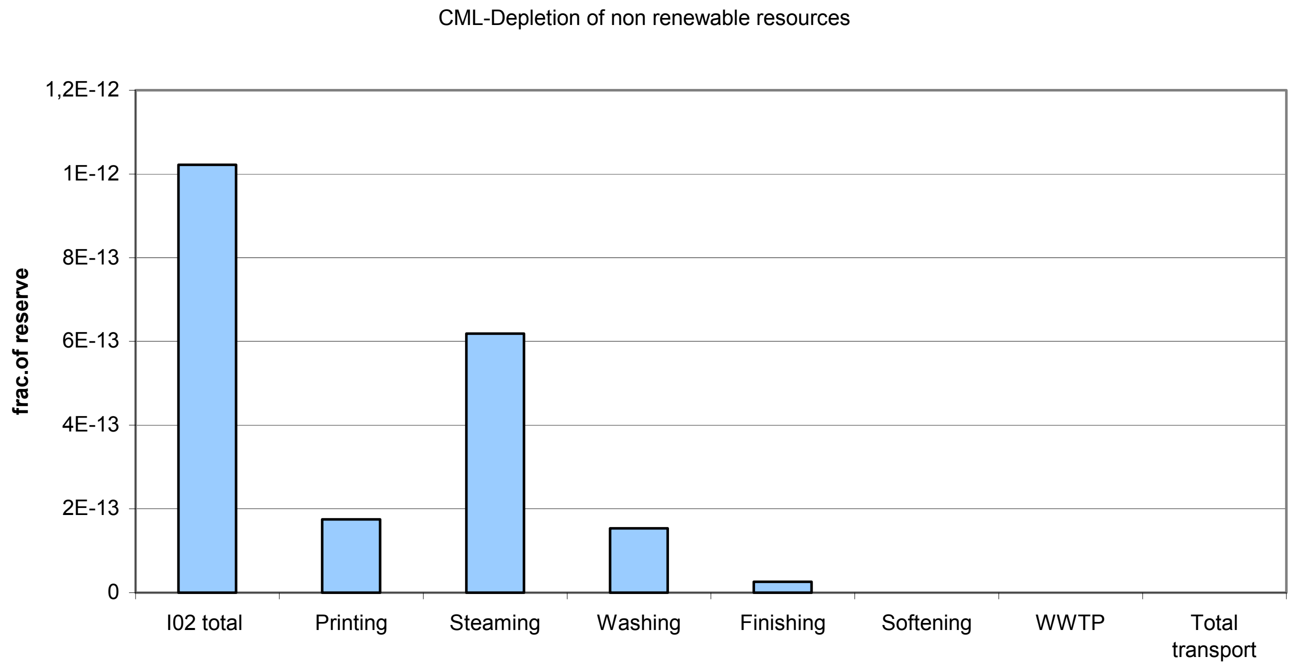

Fig. 5.6 CML 92 Depletion of non renewable resources.

Impact categories	*Units*	*Chemicals production*	*Steam production*	*Electricity production*	*Transport*	*WWTP*
CML-Depletion of non renewable resources	**fraction of reserve**	10%	68%	22%	0%	0%

Table 5.4 Main contributors to the total of category.

Impact assessment	Unit		%
CML-Depletion of non renewable resources	fraction of reserve	**1,0E-12**	100%
(r) Natural Gas (in ground)	fraction of reserve	8E-13	≅ 82%
(r) Oil (in ground)	fraction of reserve	1E-13	≅ 15%
(r) Uranium (U, ore)	fraction of reserve	2E-14	≅ 2%
(r) Iron (Fe, ore)	fraction of reserve	5E-15	≅ 1%

Table 5.5 Main contaminant fluxes.

5.1.6 Eutrophication

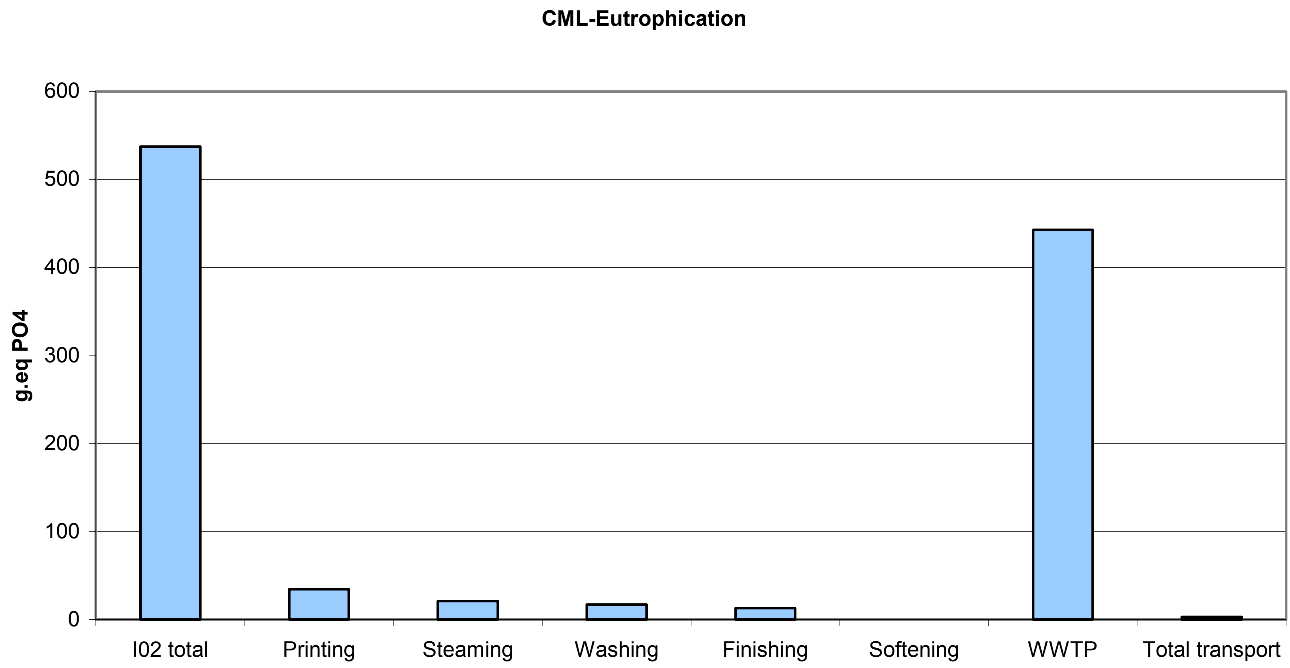

Fig. 5.7 CML 92 Eutrophication.

Impact categories	*Units*	*Chemicals production*	*Steam production*	*Electricity production*	*Transport*	*WWTP*
CML-Eutrophication	**g eq. PO4**	4%	3%	7%	1%	82%

Table 5.6 Main contributors to the total of category.

Impact assessment	**Unit**		**%**
CML-Eutrophication	g eq. PO4	**537**	100%
(w) Nitrogenous Matter (unspecified, as N)	g eq. PO4	273	≅ 51%
(w) Ammonia (NH4+, NH3, as N)	g eq. PO4	126	≅ 24%
(a) Nitrogen Oxides (NOx as NO2)	g eq. PO4	67	≅ 12%
(w) COD (Chemical Oxygen Demand)	g eq. PO4	53	≅ 10%
(a) Ammonia (NH3)	g eq. PO4	16	≅ 3%

Table 5.7 Main contaminant fluxes.

5.1.7 Greenhouse effect (100 years)

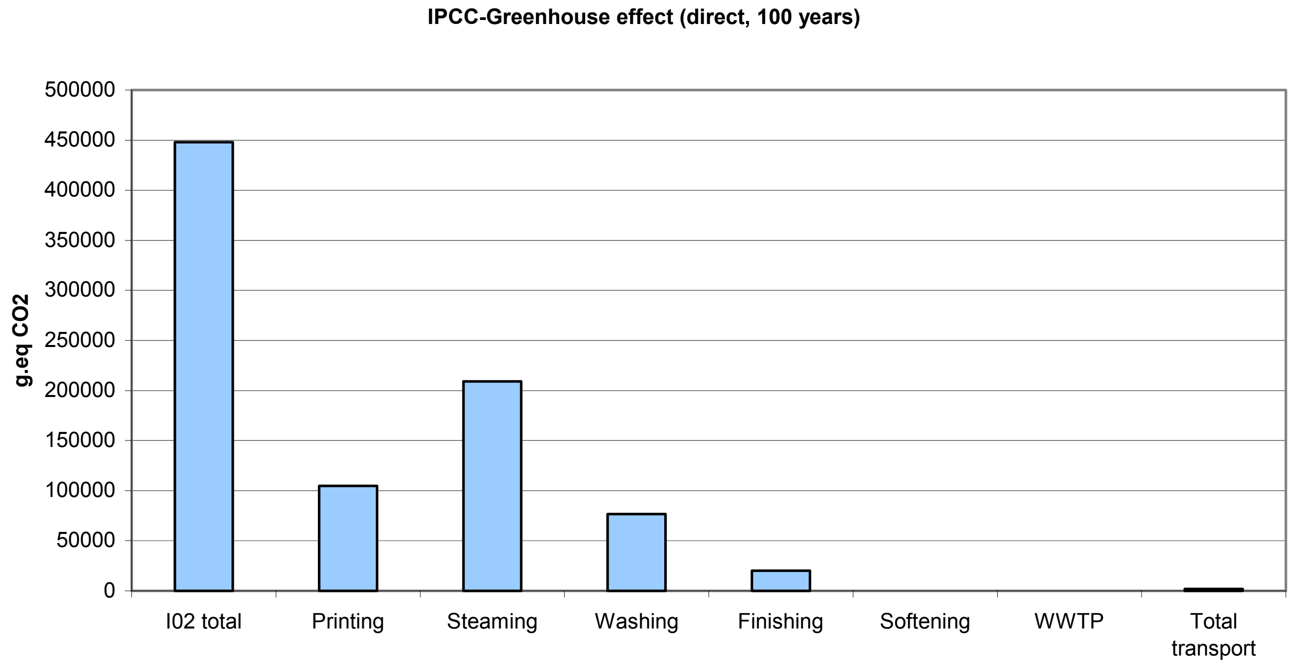

Fig. 5.8 CML 92 IPCC Greenhouse effect.

Impact categories	***Units***	***Chemicals production***	***Steam production***	***Electricity production***	***Transport***	***WWTP***
IPCC-Greenhouse effect (direct, 100 years)	**g equivalent CO2**	10%	50%	39%	0%	0%

Table 5.8 Main contributors to the total of category.

Impact assessment	**Unit**		**%**
IPCC-Greenhouse effect (direct, 100 years)	g eq. CO2	**448037**	100%
(a) Carbon Dioxide (CO2, fossil)	g eq. CO2	406913	≅ 91%
(a) Methane (CH4)	g eq. CO2	39892	≅ 9%

Table 5.9 Main contaminant fluxes.

5.1.8 Aquatic toxicity

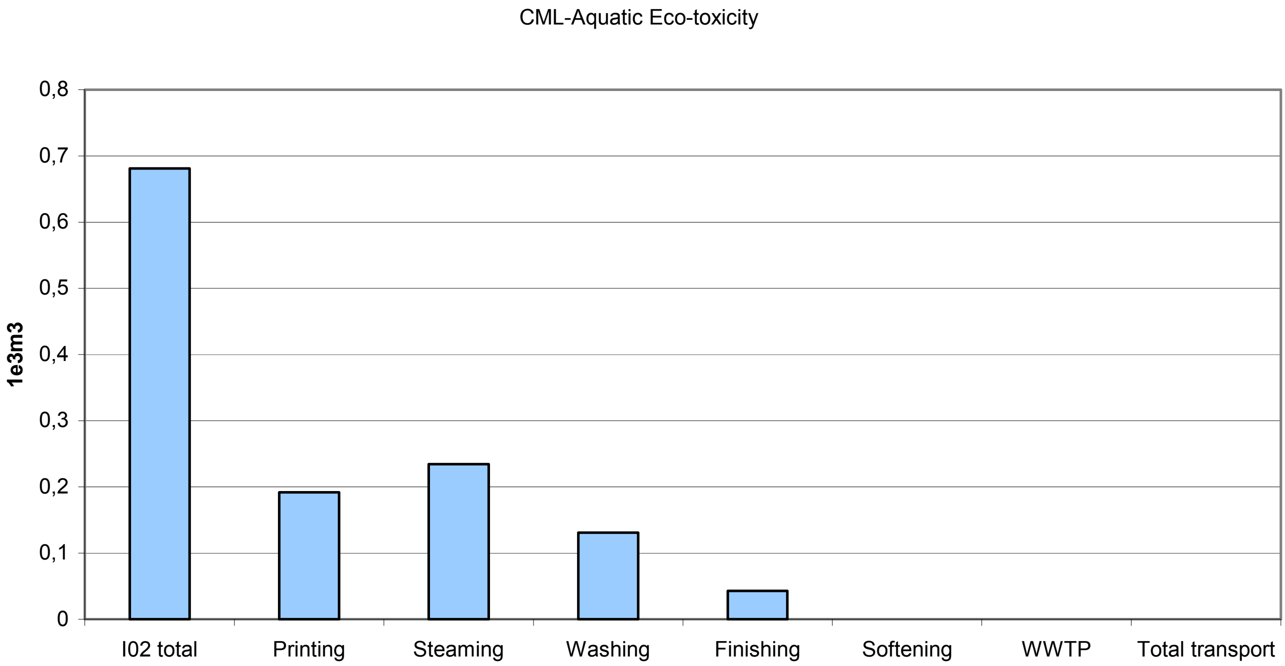

Fig. 5.9 CML 92 Aquatic ecotoxicity.

Impact categories	*Units*	*Chemicals production*	*Steam production*	*Electricity production*	*Transport*	*WWTP*
CML-Aquatic Eco-toxicity	**$1e^3$ m^3**	9%	34%	55%	0%	0%

Table 5.10 Main contributors to the total of category.

Impact assessment	Unit		%
CML-Aquatic Eco-toxicity	$1e^3$ m^3	**0,7**	100%
(w) Oils (unspecified)	$1e^3$ m^3	0,3	≅ 49%
(w) Cadmium (Cd++)	$1e^3$ m^3	0,3	≅ 42%
(w) Chromium (Cr III)	$1e^3$ m^3	0,02	≅ 3%
(w) Chromium (Cr III, Cr VI)	$1e^3$ m^3	0,02	≅ 3%
(w) Benzene (C6H6)	$1e^3$ m^3	0,01	≅ 2%

Table 5.11 Main contaminant fluxes.

5.1.9 Human toxicity

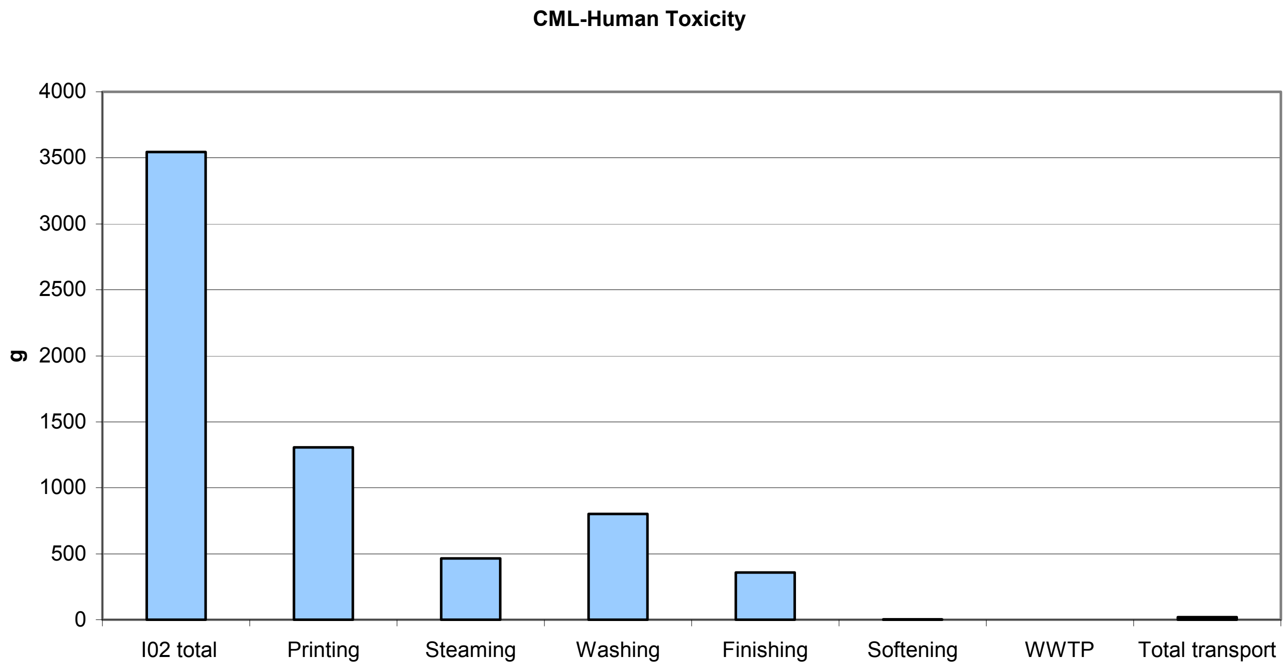

Fig. 5.10 CML 92 Human ecotoxicity.

Impact categories	*Units*	*Chemicals production*	*Steam production*	*Electricity production*	*Transport*	*WWTP*
CML-Human Toxicity	**g**	9%	7%	83%	1%	0%

Table 5.12 Main contributors to the total of category.

Impact assessment	Unit		%
CML-Human Toxicity	g	**3545**	100%
(a) Sulphur Oxides (SOx as SO2)	g	2157	≅ 61%
(a) Nickel (Ni)	g	413	≅ 12%
(a) Vanadium (V)	g	407	≅ 11%
(a) Nitrogen Oxides (NOx as NO2)	g	399	≅ 11%
(a) Arsenic (As)	g	103	≅ 3%
(a) Cadmium (Cd)	g	26	≅ 1%

Table 5.13 Main contaminant fluxes.

5.1.10 Terrestrial Ecotoxicity

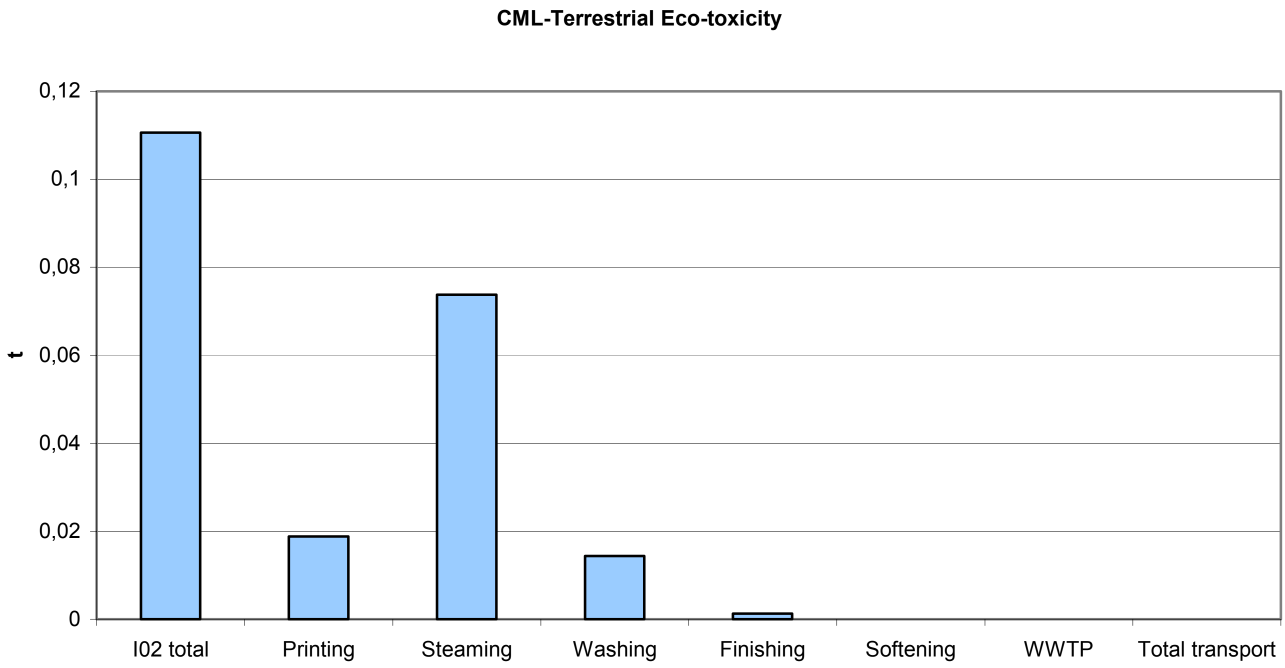

Fig. 5.11 CML 92 Terrestrial ecotoxicity.

Impact categories	***Units***	***Chemicals production***	***Steam production***	***Electricity production***	***Transport***	***WWTP***
CML-Terrestrial Eco-toxicity	**t**	14%	76%	10%	0%	0%

Table 5.14 Main contributors to the total of category.

Impact assessment	**Unit**		**%**
CML-Terrestrial Eco-toxicity	t	**0,11**	100%
(s) Zinc (Zn)	t	0,08	≅ 73%
(s) Copper (Cu)	t	0,01	≅ 12%
(s) Chromium (Cr III, Cr VI)	t	≅ 0	≅ 4%
(s) Chromium (Cr III, Cr VI)	t	≅0	≅ 4%
(s) Chromium (Cr III, Cr VI)	t	≅0	≅ 4%
(s) Arsenic (As)	t	≅0	≅ 3%

Table 5.15 Main contaminant fluxes.

5.1.11 Photochemical oxidant formation

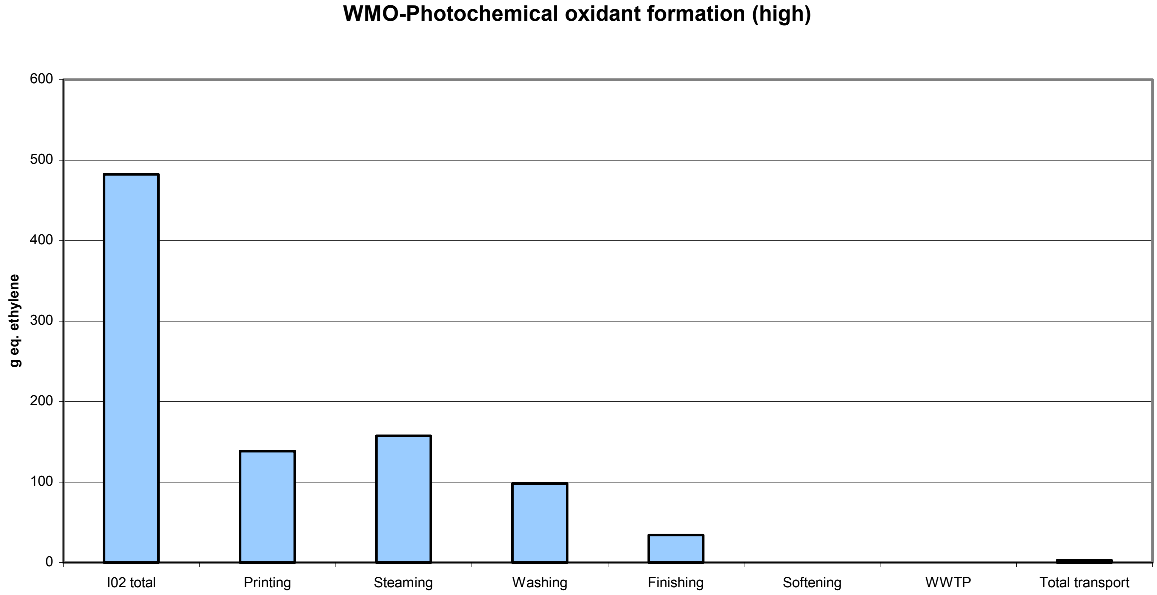

Fig. 5.12 WMO Photochemical oxidant formation (high).

Impact categories	*Units*	*Chemicals production*	*Steam production*	*Electricity production*	*Transport*	*WWTP*
WMO-Photochemical oxidant formation (high)	**g eq. ethylene**	6%	24%	53%	1%	0%

Table 5.16 Main contributors to the total of category.

Impact assessment	Unit		%
WMO-Photochemical oxidant formation (high)	g eq. ethylene	**482**	100%
(a) Hydrocarbons (except methane)	g eq. ethylene	294	≅ 61%
(a) Methane (CH4)	g eq. ethylene	50	≅ 10%
(a) Ethylene (C2H4)	g eq. ethylene	50	≅ 10%
(a) Aldehyde (unspecified)	g eq. ethylene	20	≅ 4%
(a) Propane (C3H8)	g eq. ethylene	18	≅ 4%
(a) Ethane (C2H6)	g eq. ethylene	17	≅3%
(a) Alkane (unspecified)	g eq. ethylene	17	≅3%
(a) Butane (n-C4H10)	g eq. ethylene	10	≅2%

Table 5.17 Main contaminant fluxes.

5.1.12 Impact of chemicals production

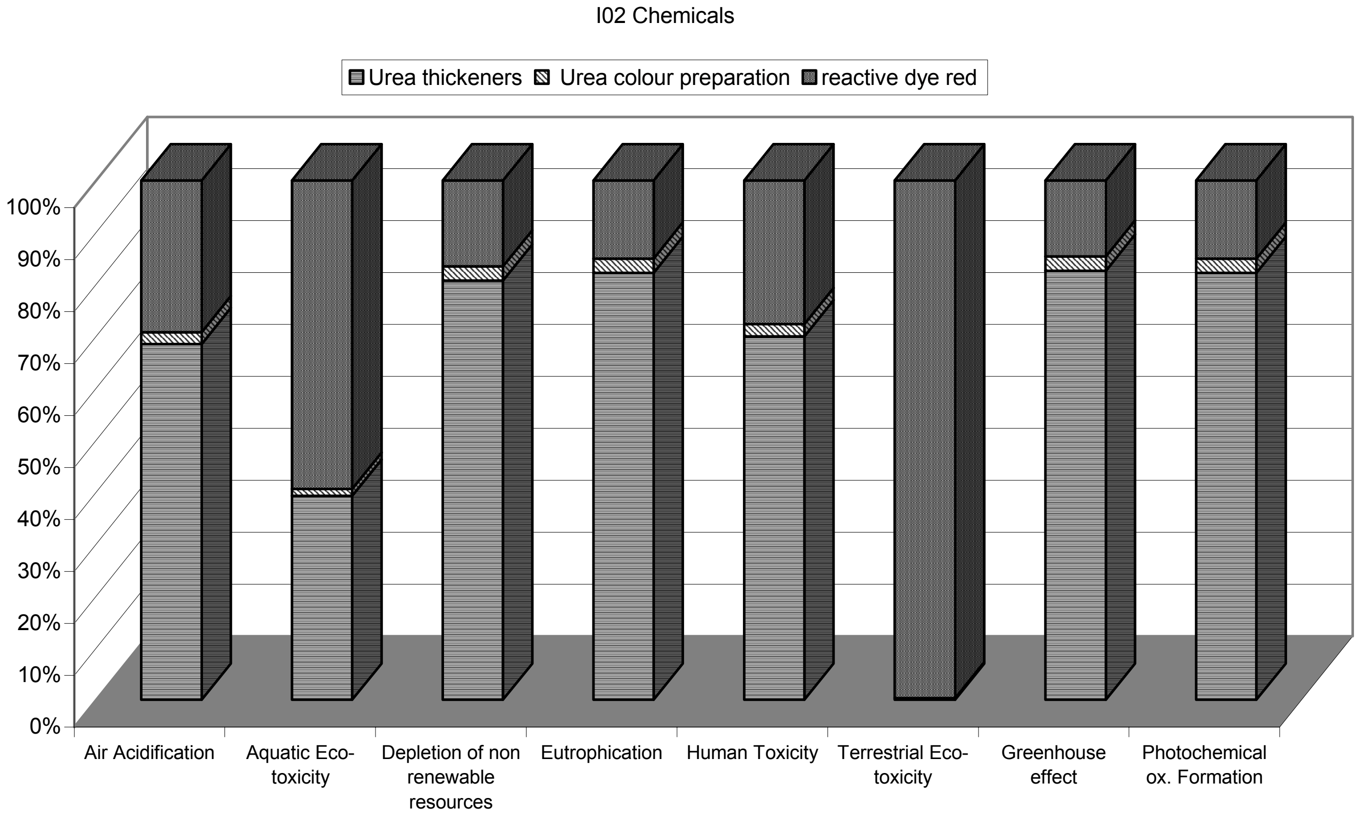

Fig. 5.13 Chemicals production contribution to impact assessment categories.

5.1.13 Chemicals ecotoxicity (screening)

Processes in systems A, B do not use chemicals classified with risk phrases R50, R51, R52, R53, R54, R55, R56, R57, R58 and so the total score of the two systems is 0.

5.2 Comparison of System A and System B

Inventory and impact assessment results of System A (electronic table reactive printing) have been compared to the results of System B (rotary machine reactive printing).

5.2.1 Energy indicators and water consumption, COD and TSS emissions.

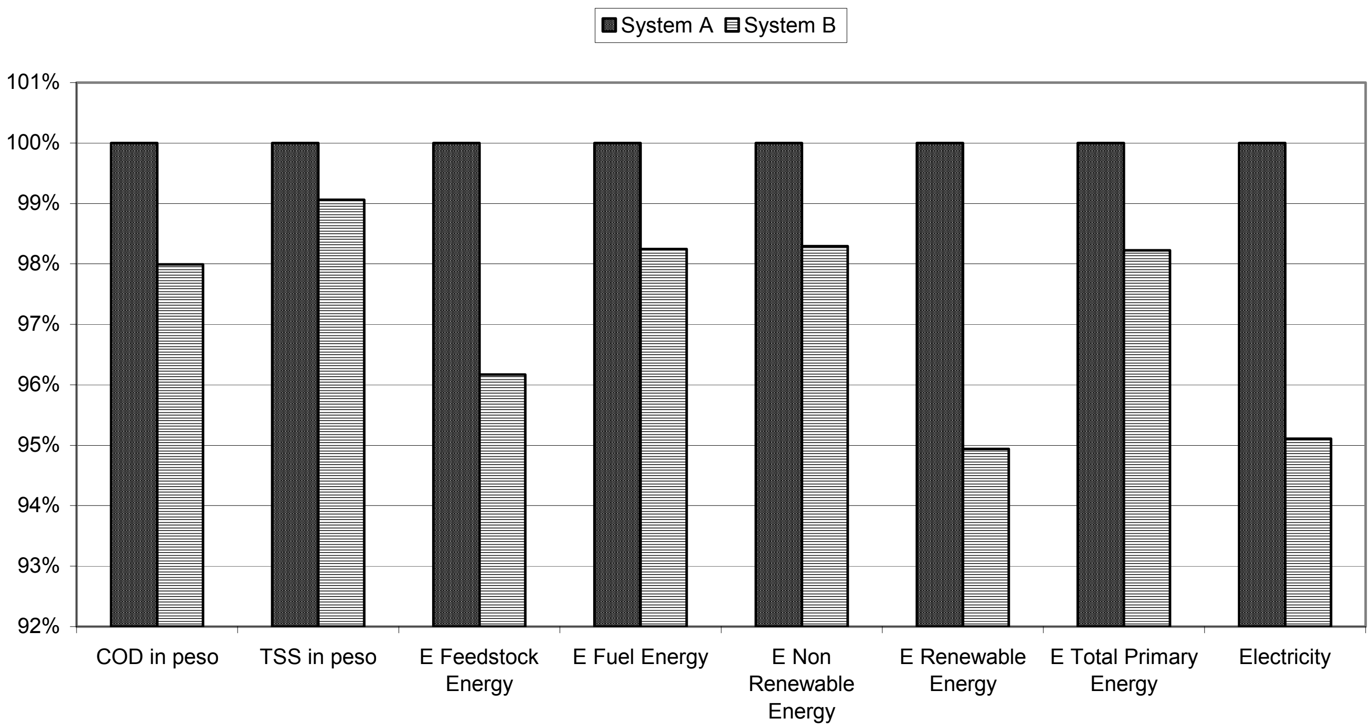

Fig. 5.14 Comparison of selected inventory data for systems A, B.

System A and B differ only for the printing process. The slightly better energy indicators of system B can be explained with the smaller energy consumption of the rotary machine which depends on the lower duration of the operating cycle (the absorbed power and the processed fabric per run are the same for the two machines).

5.2.2 Environmental impact categories

As shown in Fig 5.15 the smaller amount of electricity absorbed for system B is the cause of its slightly reduced environmental impacts for all the analyzed categories.

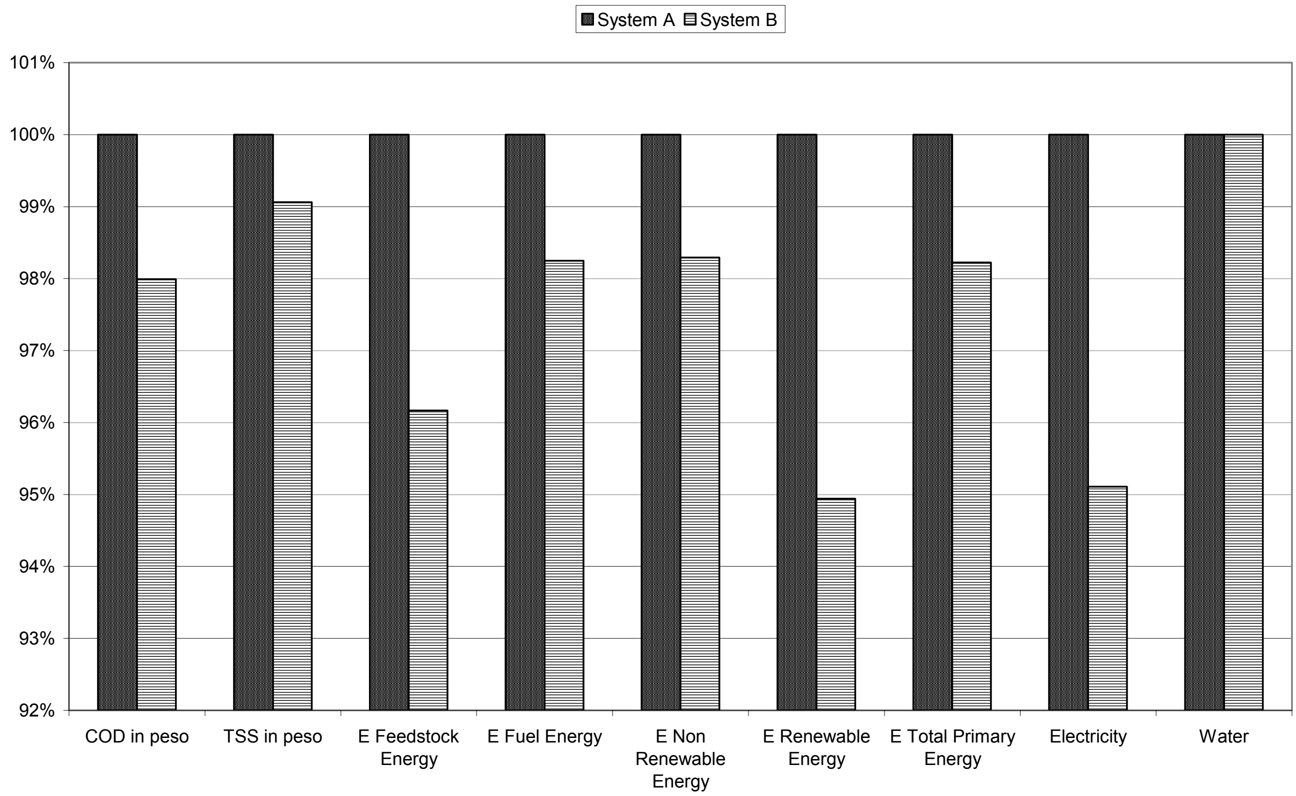

Fig. 5.15 Comparison of selected impact categories for systems A, B

5.3 Evaluation

5.3.1 Completeness check

Because in this study inventory data on 29% in weight of the total used chemicals have been collected, we decided to check the sensitivity of results to this lack of data.

5.3.2 Sensitivity check

5.3.2.1 Lack of data about chemicals

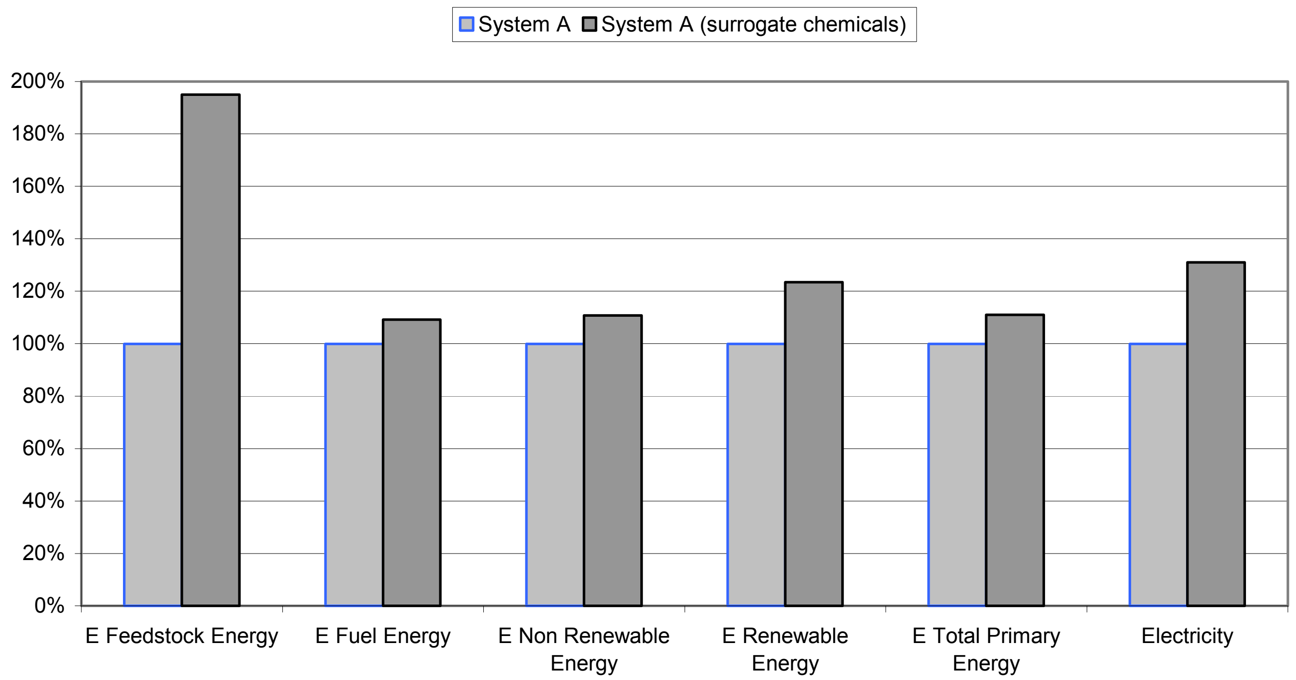

Fig. 5.16 Energy indicators for System A

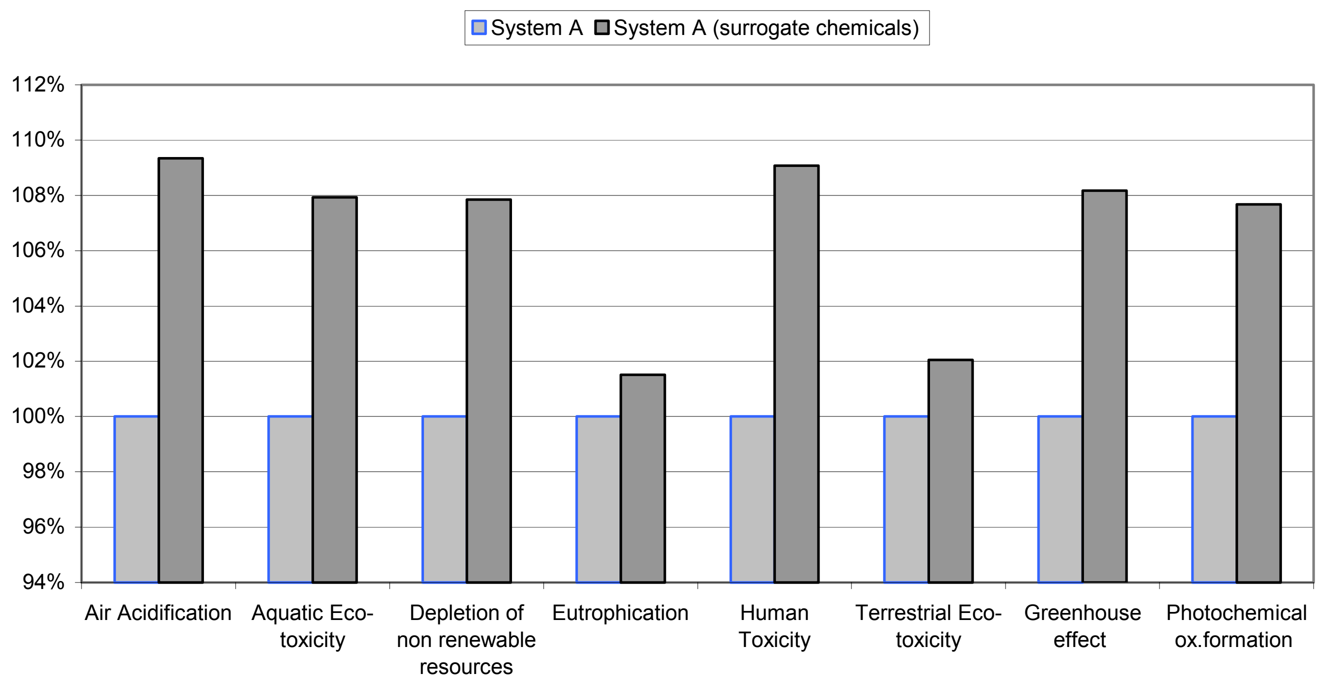

Fig. 5.17 Impact categories for System A

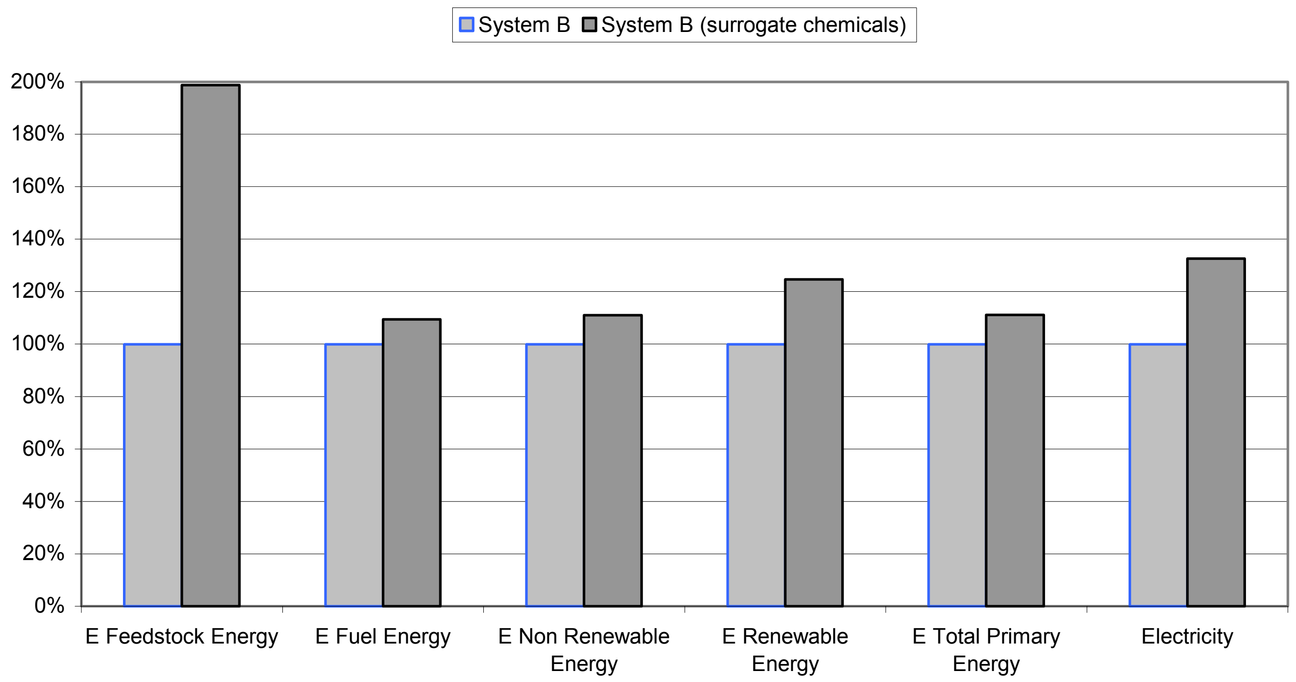

Fig. 5.18 Energy indicators for System B

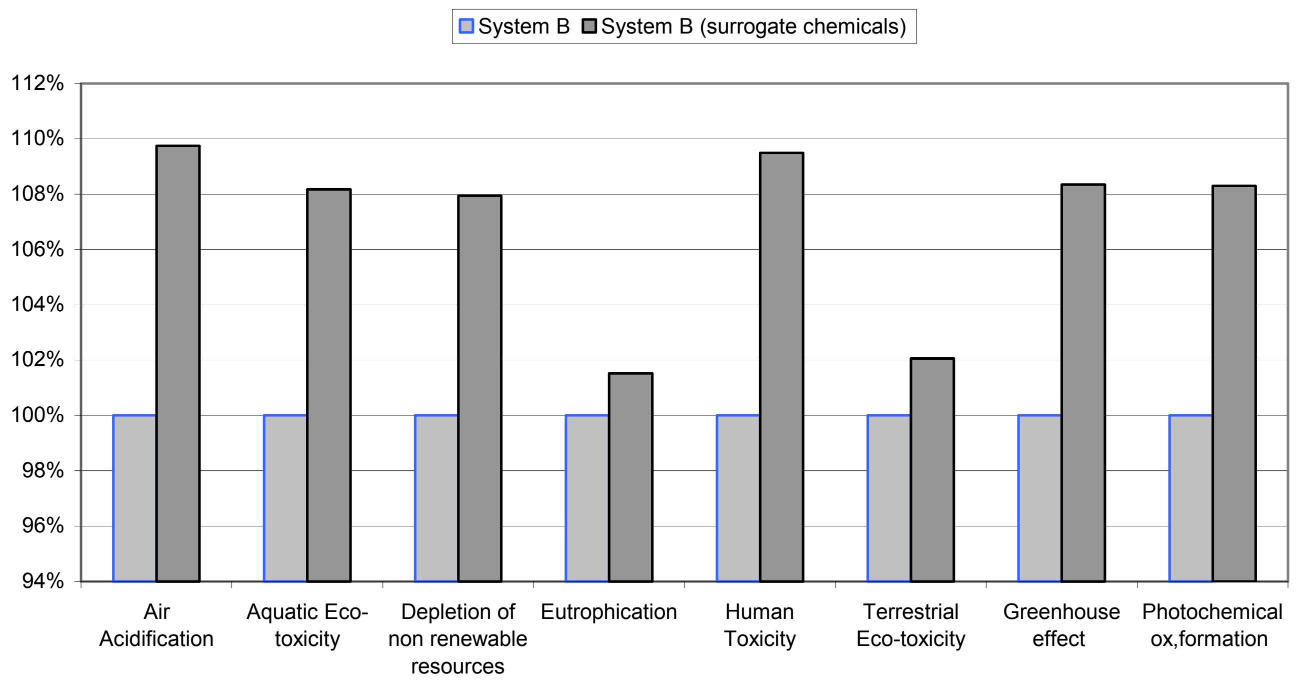

Fig. 5.19 Impact categories for system B

5.3.2.2 Allocation of thermal energy

The allocation rule applied for the definition of process specific steam and methane consumption (described in Chapter 3.2.1.3) is based on theoretic calculations and not on direct measures. The final results of the study identified steam consumption as a significant issue for several inventory and impact categories. A sensitivity check was necessary to analyse the effect of the uncertainty of this aspect to the final results. Figures 5.20-5.23 show comparison of final results in the hypothesis of a steam consumption increased by 10%.

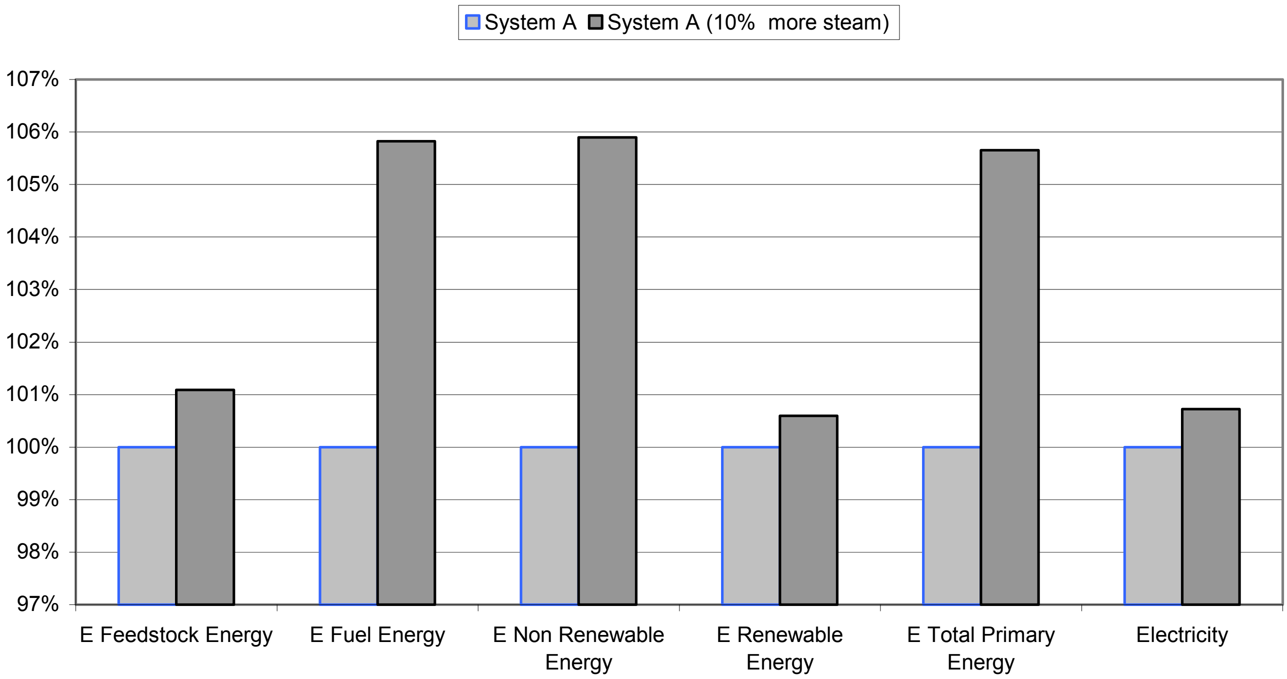

Fig. 5.20 Energy indicators for System A

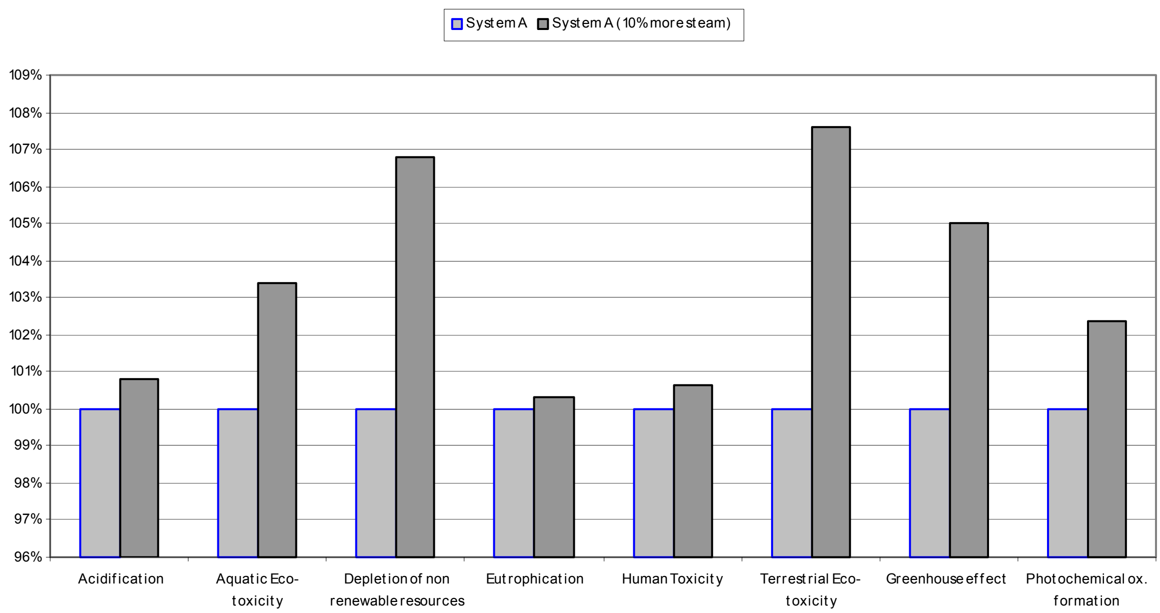

Fig. 5.21 Impact categories for System A

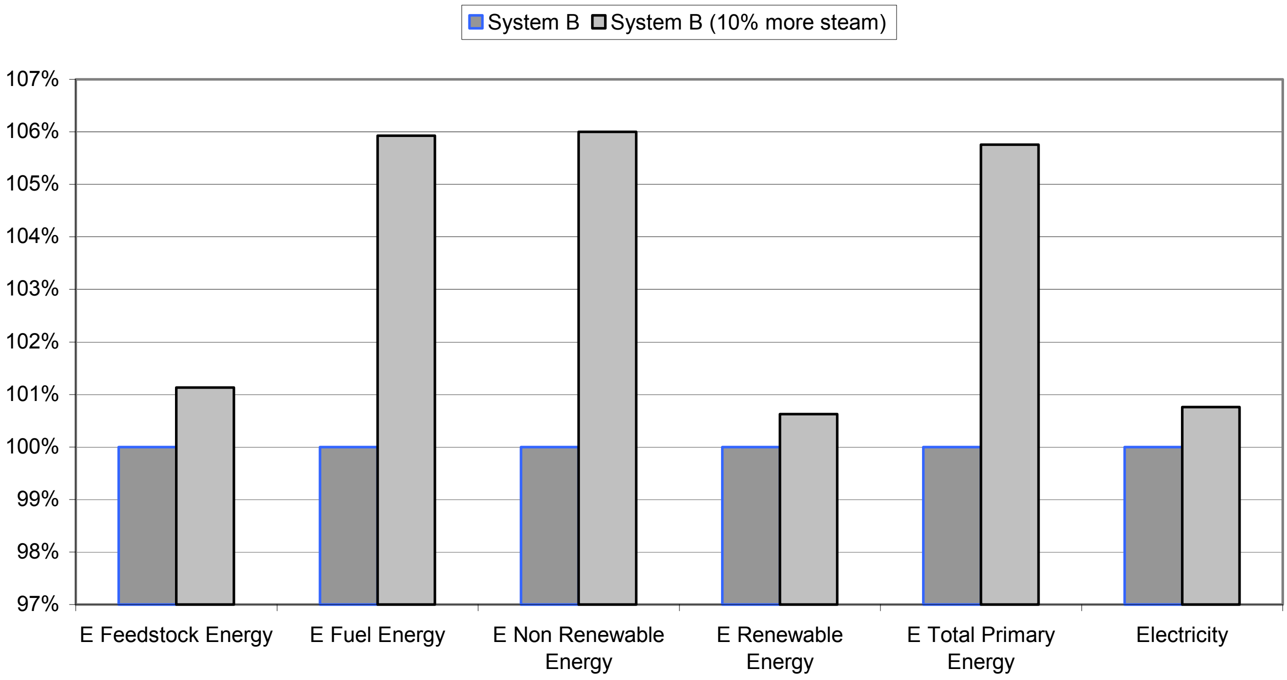

Fig. 5.22 Energy indicators for System B

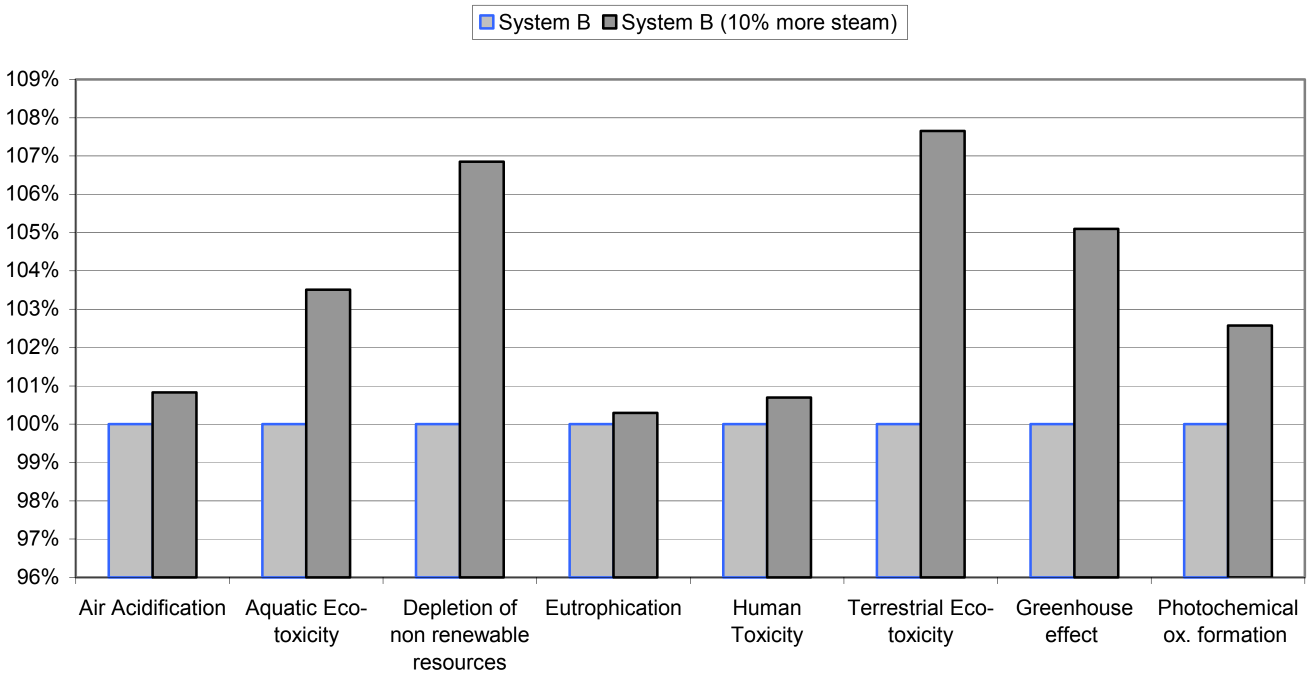

Fig. 5.23 Impact categories for System B

5.3.3 Consistency check

This LCA study can be considered consistent. Most of the data are from PIDACS or from TEAM 3.0 modules which guarantee a good general consistency. The only process having a different origin is the waste water treatment plant, which influence on the overall system is limited.

6 Conclusions

At the end of the study the following main conclusions can be drawn:

- In the chosen system life cycle the most part of water (75%) is used in the washing process and is drawn from the company wells. The water used outside the company gates for chemicals and energy production is only a small fraction of the total water. To treat 100 kg of viscose fabric almost 35 cubic meters of water are needed.
- The printing process is the main contributor to COD and TSS emissions, because of the table continuous washing at the end of printing.
- The process of steaming (G1) is the main user of the total primary energy (57%) and consequently, the main contributor to energy related environmental impact categories (greenhouse effect, depletion of resources), as well as toxicity related ones (aquatic and terrestrial toxicity). The impacts determinant is the methane combustion needed for production of steam.
- Electric energy production is an important pollutants source mainly for acidification and aquatic and human toxicity categories (respectively 77%, 55% and 83% contribution) , because of heavy use of fossil fuels for producing Italian electric energy.
- The contribution of chemicals production to environmental impact categories ranges from 4% to 14%. The significant lack of inventory data (available only for 29% in weight of the used chemicals) influences only for less than 10% all the analysed categories, showing how the study conclusions maintain their validity within the declared scope. The high influence of the missed data on the feedstock energy consumption showed by the sensitivity analysis, can be explained by the low absolute value of the feedstock energy used within the system boundaries.
- WWTP impacts are not significant for all impact categories except eutrophication (82% of the total impact) because of emissions of treated effluent to Lambro river.
- Process specific steam consumptions were calculated applying an allocation rule based on the estimation of the energy needed for heating the process water. A sensitivity check demonstrated that a 10% uncertainty of this calculation influences mostly terrestrial ecotoxicity and depletion of resources (difference by more than 5%).
-

7 References

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Annex 1: Structure and content of PIDACS

1) NOTES ON DATA COLLECTION.

- Reference year:.
- Sampling and data collection period:
- Compiler name:
- Company contact people:

2) GENERAL DATA.

a) Production:

Reference year:

Fiber	*Type*	*(%) of total weight*	*processed linear meters/yr*	*kg per linear meter*	*processed kg/yr*
TOTAL:					

Notes:

b) Water use:

<u>b.1) Supplied water</u>:

Reference year:

Source	*Quantity [m^3/yr]*	*Specific Cost [€/m^3]*	*Energy consumption [kWh/m^3]*
TOTAL:			

Notes:

<u>b.2) Process water and treatment for internal use:</u>

Reference year:

Water type	*Source*	*Treatment*	*Use*	*Quantity [m^3/yr]*	*Treatment specific cost [€/m^3]*
W1					
W2					
W3					
…					

Notes:

b.3) Process water analytic features:

Reference year:

Type	*W1*	*W2*	*W3*	*W4*	*W5*	*W6*	*W7*
T [°C]							
pH [-]							
Conductivity [mS/cm]							
COD [mg/l]							
TSS [mg/l]							
Hardness [°F]							
Chlorides [mg/l]							
Sulphates [mg/l]							
Sulphides [mg/l]							
Total phosphorous [mg/l]							
NO2-N [mg/l]							
NO3-N [mg/l]							
NH4-N [mg/l]							
TKN [mg/l]							
Hexavalent chrome[mg/l]							
Trivalent chrome [mg/l							
Iron [mg/l]							
Copper [mg/l]							
Zinc [mg/l]							
Lead [mg/l]							
Cadmium [mg/l]							
MBAS [mg/l]							
BiAS [mg/l]							

Notes:

b.4) Steam production:

Reference year:

Steam type	*Water type*	*Quantity [t/yr]*	*T max [°C]*	*Use*
S1				

Notes:

b.5) Discharged water:

Reference year:

Type	*D1* (1)	*D2*(2)	*D3*(2)	*D4*(2)	*D5*(2)	*D6*(2) (3)
Quantity [m^3/yr]						
Final destination						
Features:						
T [°C]						
Conductivity [mS/cm]						
Hardness [°F]						

pH [-]						
COD [mg/l]						
BOD5 [mg/l]						
TSS [mg/l]						
TKN [mg/l]						
N-NH4 [mg/l]						
N-NO2 [mg/l]						
N-NO3 [mg/l]						
Ptot [mg/l]						
Absorbance 420 nm						
Absorbance 550 nm						
Absorbance 680 nm						
Anionic surf. [mgMBAS/l]						
Non-ionic surf. [mgBiAS/l]						
Cationic surf. [mg/ l]						
Chlorides [mg/l]						
Chlorine [mg/l]						
AOX [mg/l]						
Chrome [mg/l]						
Copper [mg/l]						
Endocrine activity						
Hydrocarbons [mg/l]						
Iron [mg/l]						
Manganese [mg/l]						
Nickel [mg/l]						
Zinc [mg/l]						
Toxic Units (for algae)						
Toxic Units (for fish)						
Toxic Units (for bacteria)						
Toxic Units (for invertebrates)						

Notes:

c) *ENERGY CONSUMPTIONS:*

Reference year:

Source	*Unit*	*Use*	*Quantity*	*Specific cost [€/]*
Methane Gas				
Electricity				

Notes:

d) *SOLID WASTES*:

Reference year:

Type	*SW1*	*SW2*	*SW3*	*SW4*		
Description						
Waste class						
Production [kg/yr]						

Disposal						
Disposal cost[€/kg]						

Notes:

e) *OFF-GAS EMISSIONS:*

e1) Identification

Reference year:

Type	*Emission source*	*Flow rate [Nm^3/h]*	*Fumes temperature [°C]*	*Abatement*	*Abatement system*
G1					
G2					
G3					
G4					
G5					
G6					
G7					
G8					
G9					

Notes:

e2) Analytical features

Reference year:

Type	*G1*	*G2*	*G3*	*G4*	*G5*	*G6*	*G7*	*G8*	*G9*
NOx [mg/Nm^3]									
CO [mg/Nm^3]									
Aldehydes [mg/Nm^3]									
VOC [mg/Nm^3]									
Acetic acid [mg/Nm^3]									
Formic acid [mg/Nm^3]									
Ammonia [mg/Nm^3]									
Particles [mg/l]									

Notes:

f) DEPARTMENTS AND WORKING TIME:

Reference year:

Department	*Operating days*	*Daily operating period*	*Weekly operating period*	*N° of shifts per days*
General facilities				
Preparation				
Dyeing				
Finishing				

Notes:

g) EQUIPMENT:

Reference year:

Department	*Equipment*	*Item*	*Quantity*	*Operating mode*	*Bath Volume [m^3]**	*Installed power [kW]*	*Absorbed power [kW]*	*Operating years*

Notes:

3) ANNEXES (***<u>all sheets have to be considered as relevant part of the whole document</u>***):

- **An.A:** ***Material flow chart***;
- **An.B:** ***Energetic flow chart***;
- **An.C:** ***Water flow chart;***
- **An.D:** ***Production model;***
- **An.E**: ***General Facilities - Process scheme;***
- **An**.**F**: ***Preparation - Process scheme;***
- **An**.**G** : ***Dyeing - Process scheme;***
- **An**.**H** : ***Finishing - Process scheme;***
- **An.I:** ***Water consumptions;***
- **An**.**L**: ***Water discharges;***
- **An.M**: ***Discharged water analytic data;***
- **An**.**N**: ***Chemicals safety data sheets.***

Example of a Process scheme (An.E-F-G-H)

Department	
Yarn	
Process	
Equipment	
Item	
Run time (h)	
Number of run/yr	
Processed yarn (kg/yr)	
Processed yarn per run (kg)	

Water type and volume

Chemicals concenration

Steam type

bath
T=...°C
t=... min

Discharge

Discharge type and volume
T [°C]=
pH [-]=;
Conductivity [mS/cm]=;
COD [mg/l]=
TSS [mg/l]=

Water type and volume

Steam type

Warm washing
T=...°C
t=... min

Discharge

Discharge type and volume
T [°C]=
pH [-]=;
Conductivity [mS/cm]=;
COD [mg/l]=
TSS [mg/l]=

Notes: