LCA OF NRG 180 HT DYEING MACHINE

FLAiNOX

In collaboration with

RINA

the innovation consulting partner

Goal of the study

The aim of the study is to **assess the energetic and environmental impacts of the NRG 180HT machine** along the entire life cycle, considering a process treating a conventional Polyester. Goal of this study is to assess the environmental impact of the chosen product, considering the CO_2, the embodied energy and other impacts as described in LCIA scope settings.

Boundary limits, functional units and any other point useful for contextualizing the report will be properly defined in the following chapters.

WHAT IS AN LCA?
Life Cycle Assessment (LCA) is a compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle. Life Cycle Assessment is a structured, comprehensive, and internationally standardized methodology, used to quantify all relevant emissions and resources consumed by a good or service and their related impact on environment, human health, and resources depletion. The LCA study is performed in accordance with internationally recognized guidelines (ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance") and standards (ISO 14044:2021 and ISO 14040:2021) main requirements that identifies a series of steps, i.e.: 1. Goal & scope definition 2. Life Inventory Analysis (LCI) 3. Life Impact Assessment (LCIA) 4. Results Interpretation

Scope of the study

Several considerations and assumptions were made to define the details of the LCA model to be developed in the GaBi LCA-dedicated software. The scope of this study is to evaluate the environmental impacts of the Flainox NRG 180HT, considering a process treating a conventional PES.

A "**cradle to grave**" LCA analysis is performed, including the raw materials extraction, materials and components production, components processing and assembly in FLAINOX facilities in Quaregna (BI), the machine transport to a client facility, the use phase and, finally, the end-of-life steps.

Function, functional unit, and reference flow

The functional unit of the analysis is the NRG 180HT machine, having a **mass of 5752 kg** and a **life span of 30 years**, performing46673 cycles per life span,

The amount of textile treated during these cycles are 7000900 kg. In the use phase a defined and repeatable dyeing process will be assessed, according to specific customer information provided to Flainox.

Moreover, also the **NRG 240HT** and **NRG 90HT** are assessed, through a conversion table created from NRG 180HT results.

The NRG 180HT is a rotary machine for dyeing garments, socks and seamless at high temperature, which is available in several configurations according to the specific customer requests. The NRG 180HT is manufactured in Quaregna, Biella, Italy and exported as final product all over the world. In this analysis a customer is considered, located in USA. Flainox in fact has a wide customer network in Asia, Africa and America.

Modelling framework

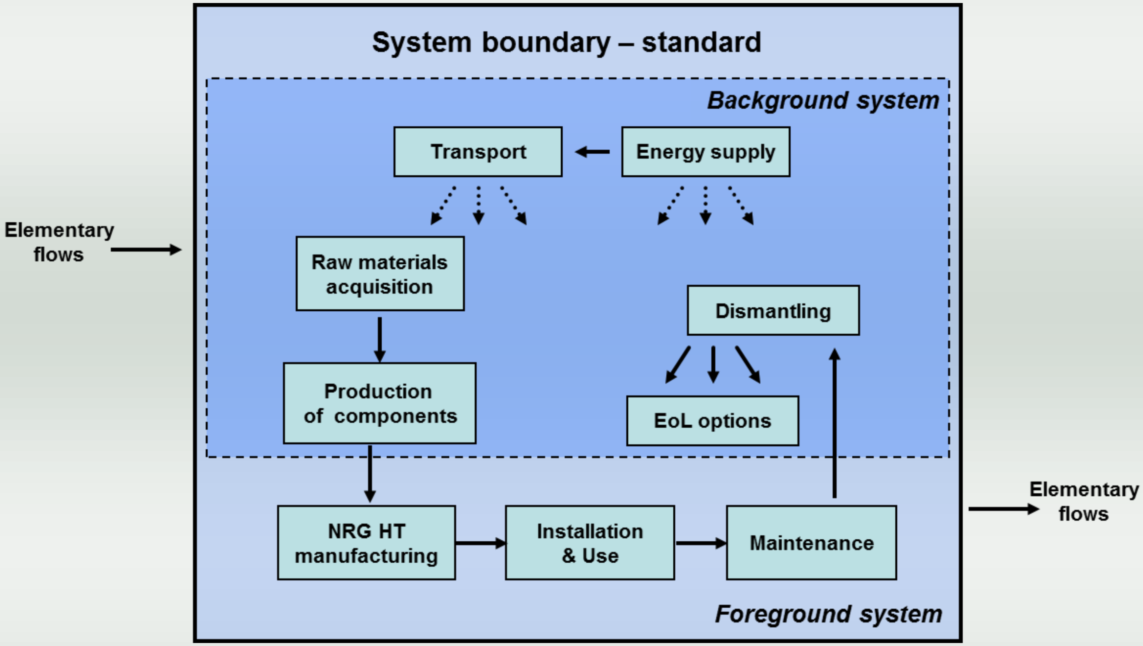
Processes in the **background** system have not been inventoried with currently available data from suppliers but included and evaluated based on data taken from dedicated databases. Waste flows belonging to such processes have been connected to disposal management processes according to the cut-off rule. Processes in the **foreground** system have been instead inventoried based on data from the owner of the technology, i.e., FLAINOX, its suppliers and the users of their machines. All the manufacturing processes which take place inside FLAINOX, the definition of standard dyeing process (according to specifications of a defined customer) and one of the three dismantling options consumptions belong to foreground system.

System boundaries

A “cradle to grave” LCA analysis is performed, including the manufacturing, transport, use, and end-of-life phases of the machine.

Regarding the **geographical boundaries**, the datasets used for the manufacturing process and end-of-life process LCA models are mainly referred to European averages. The transport operations have been modelled considering USA as installation country. Regarding the **time boundaries**, the expected lifetime of the machine is 30 years. All the phases last different timeframes: the entire cycle until the installation could be assumed to be 1 year. These estimations are surely generic because they do not take into account the specific production process of a company and its real timing of activities, but they could be considered quite factual. Besides, this choice warrants to the analysis a solid background bypassing any type of problem linked to the collection of data.

Figure below schematically represents the steps included in the analysis. Raw materials are extracted and processed before reaching the factories of different suppliers, where the single components are produced. Then they are assembled and require further manufacturing operations by Flainox and finally installed in the chosen dyeing industry. The product is then used by consumers throughout its life and finally dismantled. Transport and energy supply support all the processes in the system boundary.



NRG 180HT LCA System Boundaries

Life Cycle Inventory analysis

The Inventory analysis is the LCA phase that involves the compilation and qualitative/quantitative identification of inputs and outputs for a given product system throughout its life cycle or for a single process. The inventory analysis includes iterative data collection and the compilation of the data in a Life Cycle Inventory (LCI) table.

The Life Cycle Inventory model has been implemented through dedicated software, namely GaBi.

The main phases of NRG HT machine life cycle are:

- raw materials extraction and processing
- assembly and manufacturing operations
- transport to the customer
- use phase
- end-of-life

LCA models on GaBi have been created for the life cycle steps of the product.

The NRG 180HT is a rotary machine for dyeing garments, socks and seamless at high temperature, which is available in several configurations according to the specific customer requests.

NRG 180HT

NRG 180HT – Technical Data

Nominal Load		kg	180
Number of compartments		n.	3
Usable drum volume		m^3	3
Average power adsorbed		kW	14
Maximum speed		Rpm	450
Machine width and depth		mm	2930
			2640
Total height		mm	2880
Weight	**Machine**	kg	4483
	Basket	kg	696
	Service group	kg	352
	Electrical panel	kg	220
Max working temperature at sea-level		°C	135

The machines can be tuned by customers according to its experience, required product quality parameters, textile substrates and needed chemicals.

Therefore, a standard reference cycle does not exist, and in the following LCA analysis the practitioners have performed the assessment based on specific process defined by Flainox to investigate the environmental impact. The process of the NRG 180HT machine are intended to be used for dyeing 150 kg of PES stockings in blue/black. A lifetime of the machine equal to 30 years is considered.

Through normalization factors, the results have been extended to NRG 90HT and NRG 240HT.

For these two machines, the goal of the system is the same (dyeing conventional polyester, stocking in blue/black)) but the loads differ:

- 70 kg for NRG 90 (factor: 0,47)
- 203 kg for NRG 240 (factor: 1,35)

Life cycle impact assessment

The Life Cycle Impact Assessment (LCIA) identifies and evaluates the amount and significance of the potential environmental impacts arising from the LCI. Inputs and outputs are assigned to impact categories and their potential impacts quantified according to characterization factors.

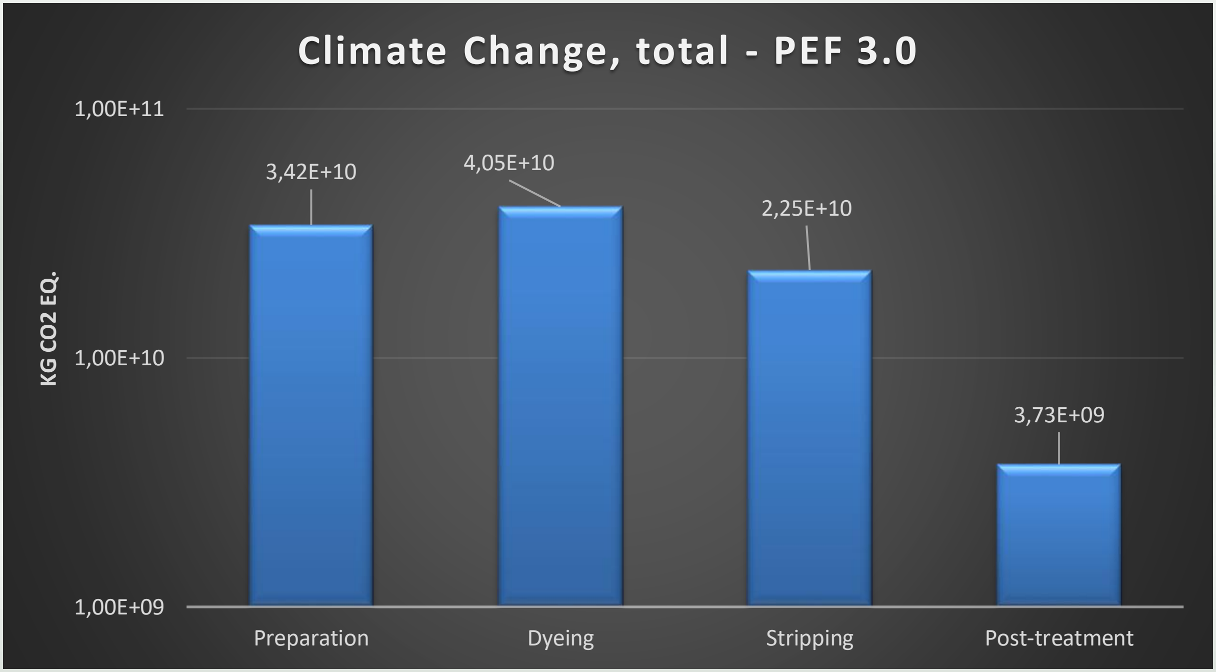
Impact category (EF3.0)	***Units***
EF 3.0 Acidification	[Mole of H+ eq.]
EF 3.0 Climate Change - total	[kg CO2 eq.]
EF 3.0 Climate Change, biogenic	[kg CO2 eq.]
EF 3.0 Climate Change, fossil	[kg CO2 eq.]
EF 3.0 Climate Change, land use and land use change	[kg CO2 eq.]
EF 3.0 Ecotoxicity, freshwater - total	[CTUe]
EF 3.0 Ecotoxicity, freshwater inorganics	[CTUe]
EF 3.0 Ecotoxicity, freshwater metals	[CTUe]
EF 3.0 Ecotoxicity, freshwater organics	[CTUe]
EF 3.0 Eutrophication, freshwater	[kg P eq.]
EF 3.0 Eutrophication, marine	[kg N eq.]
EF 3.0 Eutrophication, terrestrial	[Mole of N eq.]
EF 3.0 Human toxicity, cancer - total	[CTUh]
EF 3.0 Human toxicity, cancer inorganics	[CTUh]
EF 3.0 Human toxicity, non-cancer metals	[CTUh]
EF 3.0 Human toxicity, non-cancer organics	[CTUh]
EF 3.0 Ionising radiation, human health	[kBq U235 eq.]
EF 3.0 Land Use	[Pt]
EF 3.0 Ozone depletion	[kg CFC-11 eq.]
EF 3.0 Particulate matter	[Disease incidences]
EF 3.0 Photochemical ozone formation, human health	[kg NMVOC eq.]
EF 3.0 Resource use, fossils	[MJ]
EF 3.0 Resource use, mineral and metals	[kg Sb eq.]
EF 3.0 Water use	[m^3 world equiv.]

LCA Results

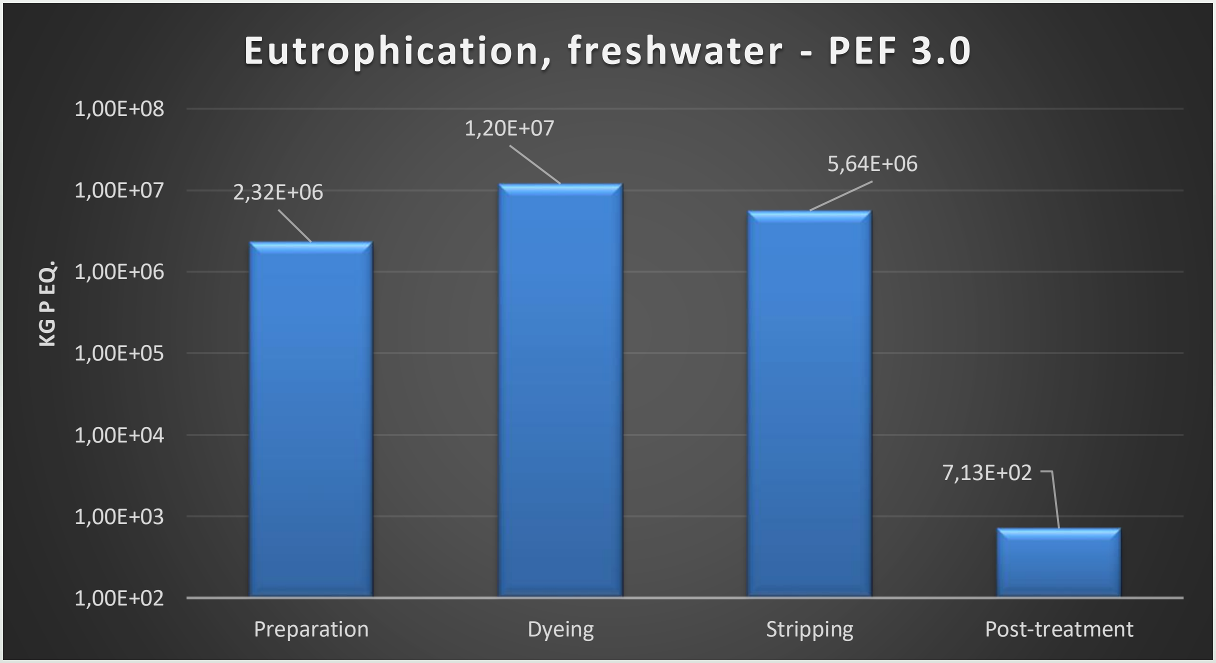
In order to have a more detailed view of the results, bar charts related to the **use phase** have been drawn starting from LCA results, since the contribution of **use phase**, compared to other ones is evident and it overcomes the 99% in all the indicators.

In particular, this analysis is focused on six most representative indicators (according to PEF 3.0 Impact assessment methodology):

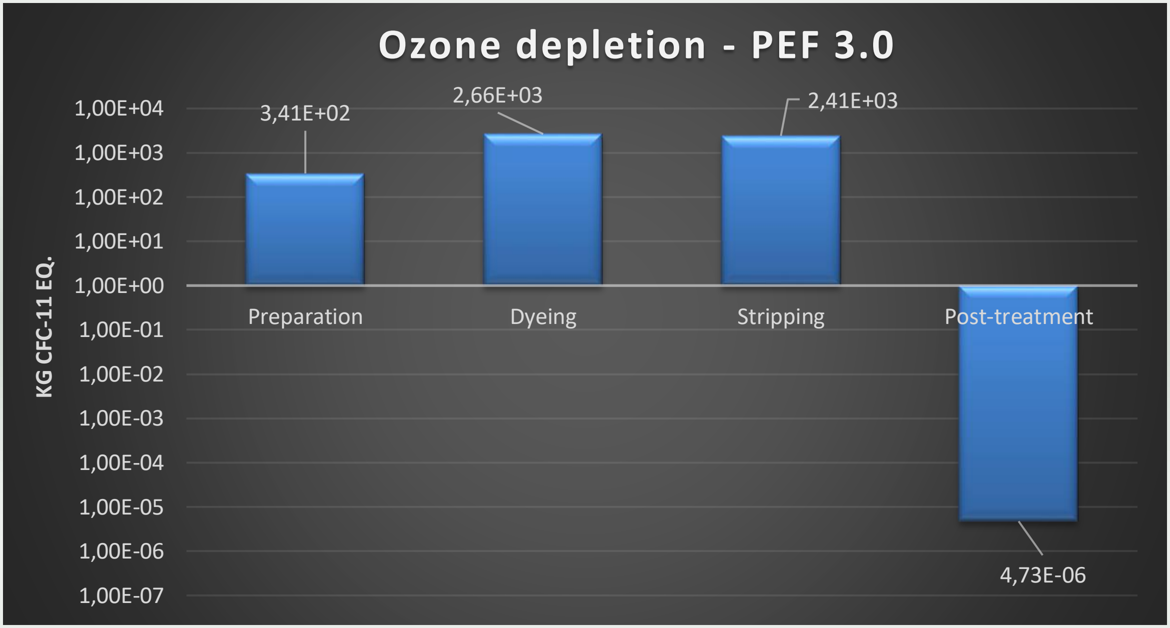
- **Climate Change, total,** which is usually one of the most understandable and well-known impact indicators, evaluating the emission of greenhouses gases (GHG)
- **Eutrophication Freshwater,** due to the high amount of water used, it evaluates the benefit from the reduction of this source in new processes, especially focusing on the effects of wastewater into environment
- **Ozone Depletion,** which evaluates the burdens on ozone-hole effect;
- **Resource Use, fossils,** which is one of the two indicators where raw materials have a noticeable impact;
- **Resource Use, mineral and metals,** which focuses on the consumption of specific raw materials from mineral and metal source;
- **Water Use,** which evaluates the depletion of water along the considered life cycles.



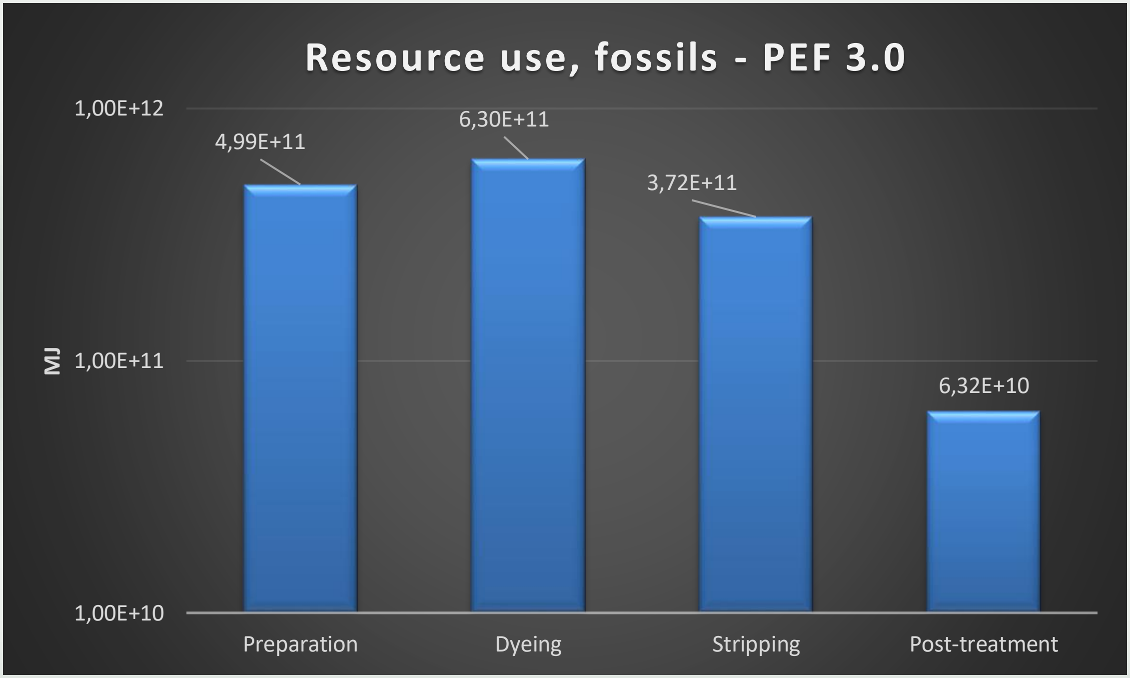
For one of the well-known indicators, the step of the use phase which has the highest impact is the **dyeing** (40%), including several chemical products. Furthermore, **preparation** and **stripping** steps have quite similar values (34% and 22%), while the lowest impact is associated to the **post-treatment** stage (which principally involves energy inputs, 4%).



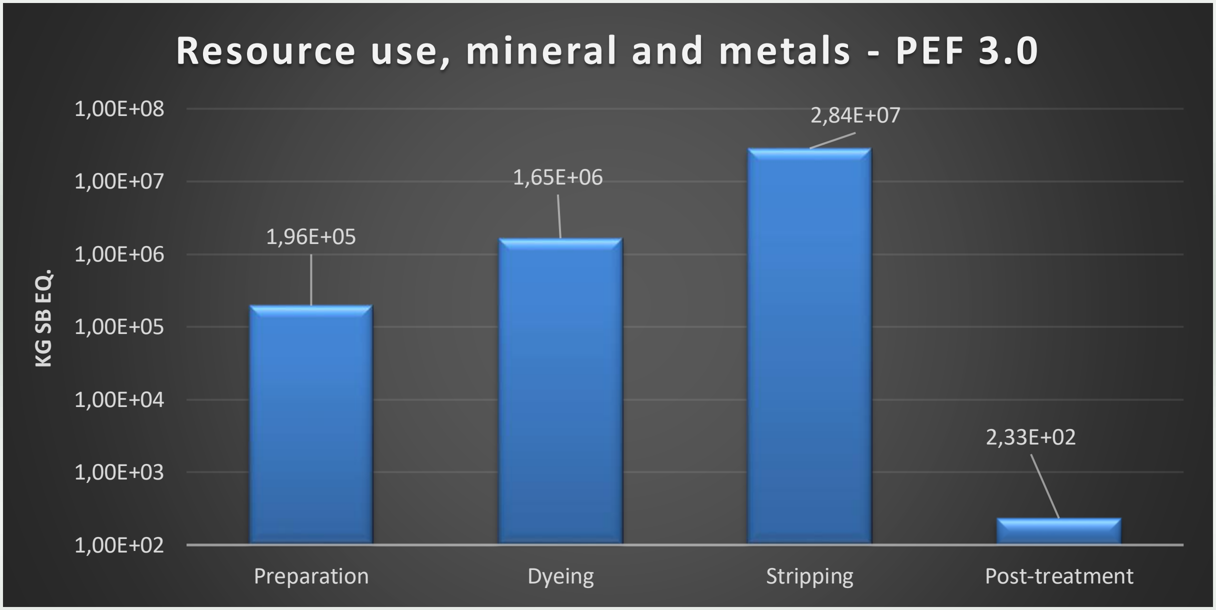
The assessment for the indicator "**Eutrophication freshwater**" outlines that the highest contribution is due to the **dying** step (60%). **Stripping** step has also a high impact (where chemicals are greatly employed, 28%); on the contrary, **preparation** step shows a not remarkable value (12%), and the post treatment contribution one is almost negligible.



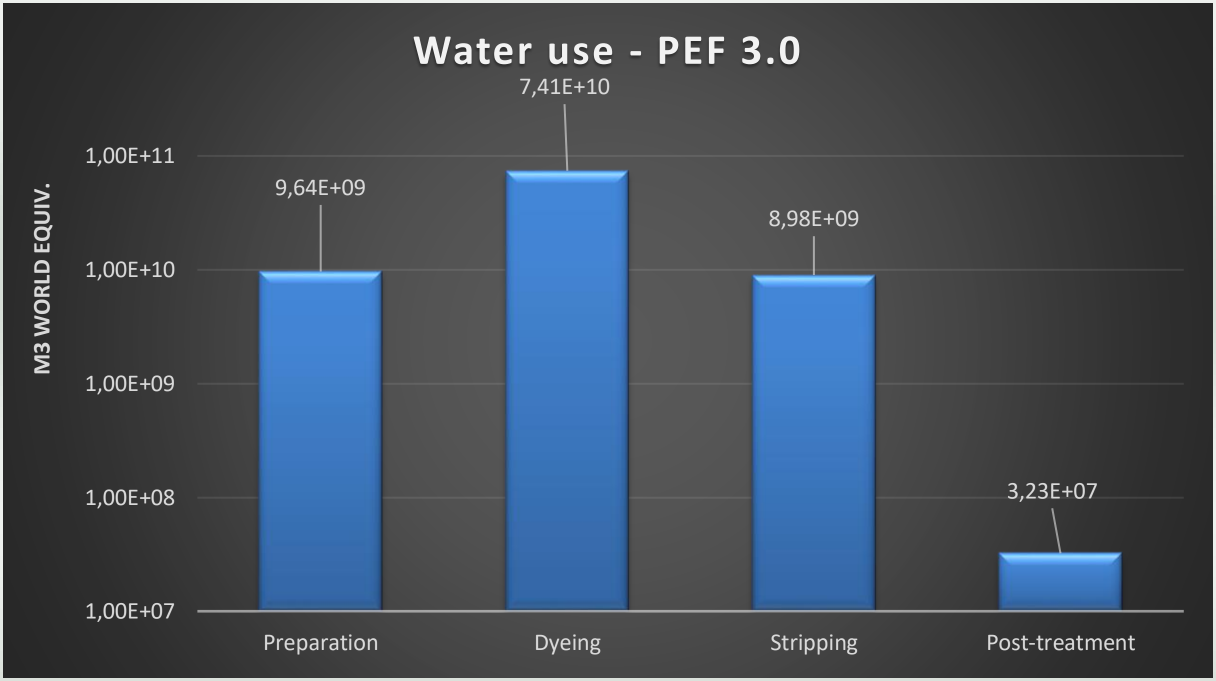
The **Ozone Depletion** highest value is associated to the **dyeing** step of the use phase (49%) probably due to the high consumption of chemicals and energy inputs. Significant impact is observed in the **stripping** step (45%). Finally, the **preparation** (6%) and **post-treatment** (almost negligible) processes shows again a low contribution.



The indicator "**Resource use, fossils**" reports its higher values for the **dyeing** stage (40%). Then, **preparation** step also has high demand of energy and raw materials (32%). Finally, **stripping** process presents a remarkable value (24%), while **post treatment** impact is almost insignificant.



Regarding the indicator "**Resource use, mineral and metals**", the analysis outlines that the **stripping** step of the use phase has the highest impact (94%); **dyeing** step contribution is of 5%, while the other two steps can be considered negligible.



Finally, the depletion of water in the use phase of NRG 180HT is highest during the **dyeing** step (80%). On the other side, a low contribution is observed for the stripping, and preparation steps (10% for each step). Post treatment can be again considered insignificant.

CONCLUSIONS

The LCA study described in this document has been performed by RINA Consulting in accordance with main requirements of international standards (ISO 14040:2021 and 14044:2021) and internationally recognized guidelines (i.e., ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance).

The report provides indications on the environmental footprint of one of the main products of Flainox catalogue, the NRG 180HT machine. The main outcome of the study is that contribution of use phase, compared to other ones is evident and it overcomes the 99% in all the indicators.

References

ISO 14040:2021, Environmental management -- Life cycle assessment -- Principles and framework, 2021.

ISO 14044:2021, Environmental management -- Life cycle assessment -- Requirements and guidelines, 2021.

DG JRC/IES, ILCD Handbook, 2011.

Gabi database and software, https://gabi.sphera.com/italy/index/

Flainox, Internal Documentation related to materials and energy consumptions, waste produced, and information related to the use phase, 2021

Flainox, Internal Documentation related to Report LCA and Executive summary 2015 version)

EU Commission, Product Environmental Footprint Pilot Guidance, Guidance for the implementation of the EU Product Environmental Footprint (PEF) during the Environmental Footprint (EF) pilot phase, 2016

EU Recommendations 2013/179, Commission Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations, 2013

ISO and SETAC Europe (modified from Heijungs & Hofstetter), Terminology used in life cycle assessment as defined by (ISO, 1997a; 1997b; 1997d), 1996.

Institute of Environmental Sciences, Leiden University, The Netherlands: Handbook on impact categories "CML 2001 ", 2001.

Institute of Environmental Sciences, Leiden University, The Netherlands: "Life Cycle Assessment, An use guide to the ISO standards, Volume 1, 2 and 3", 2001.

IPCC, Climate change 2007. Impacts, adaptations and mitigation of climate change: Scientific and technical analysis. Intergovernmental Panel on Climate Change, Cambridge, University Press, New York, 2008.

ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level Mark Goedkoop, 6 January 2009.

Results for NRG 90HT and NRG 240HT

Starting from impacts obtained for NRG 180HT, two conversions have been conducted to evaluate the impacts only of the Use Phase of two different models of the same series NRG HT, NRG 90HT and NRG 240HT.

The Use Phase is the main impacting one and the results have been converted for NRG 90HT and NRG 240HT, through the following factors:

- 0,47 for NRG 90HT
- 1,35 for NRG 240HT.

The results, including the **Use Phase** only, are presented in the following tables.

INDICATOR	Value	Reference unit
EF 3.0 Acidification	2.85E+08	[Moles of H+-Equiv.]
EF 3.0 Climate Change - total	4.75E+10	[kg CO2 eq.]
EF 3.0 Climate Change, biogenic	1.19E+08	[kg CO2 eq.]
EF 3.0 Climate Change, fossil	4.17E+10	[kg CO2 eq.]
EF 3.0 Climate Change, land use and land use change	5.69E+09	[kg CO2 eq.]
EF 3.0 Ecotoxicity, freshwater - total [CTUe]	1.07E+12	[CTUe]
EF 3.0 Ecotoxicity, freshwater inorganics [CTUe]	2.98E+11	[CTUe]
EF 3.0 Ecotoxicity, freshwater metals	6.63E+11	[CTUe]
EF 3.0 Ecotoxicity, freshwater organics	1.10E+11	[CTUe]
EF 3.0 Eutrophication, freshwater	9.35E+06	[kg P eq.]
EF 3.0 Eutrophication, marine	6.58E+07	[kg N eq.]
EF 3.0 Eutrophication, terrestrial	3.63E+08	[Mole of N eq.]
EF 3.0 Human toxicity, cancer - total	1.38E+03	[CTUh]

INDICATOR	Value	Reference unit
EF 3.0 Human toxicity, cancer inorganics	1.23E-09	[CTUh]
EF 3.0 Human toxicity, cancer metals	1.36E+03	[CTUh]
EF 3.0 Human toxicity, cancer organics	2.02E+01	[CTUh]
EF 3.0 Human toxicity, non-cancer - total	5.88E+02	[CTUh]
EF 3.0 Human toxicity, non-cancer inorganics	7.96E+01	[CTUh]
EF 3.0 Human toxicity, non-cancer metals	4.76E+02	[CTUh]
EF 3.0 Human toxicity, non-cancer organics	3.63E+01	[CTUh]
EF 3.0 Ionising radiation, human health	3.56E+09	[kBq U235 eq.]
EF 3.0 Land Use	4.27E+11	[Pt]
EF 3.0 Ozone depletion	2.54E+03	[kg CFC-11 eq.]
EF 3.0 Particulate matter	2.21E+03	[Disease incidences]
EF 3.0 Photochemical ozone formation, human health	1.04E+08	[kg NMVOC eq.]
EF 3.0 Resource use, fossils	7.35E+11	[MJ]
EF 3.0 Resource use, mineral and metals	1.42E+07	[kg Sb eq.]
EF 3.0 Water use	4.36E+10	[m^3 world equiv.]

INDICATOR	Value	Reference Unit
EF 3.0 Acidification	8.18E+08	[Moles of H+-Equiv.]
EF 3.0 Climate Change - total	1.36E+11	[kg CO2 eq.]
EF 3.0 Climate Change, biogenic	3.43E+08	[kg CO2 eq.]
EF 3.0 Climate Change, fossil	1.20E+11	[kg CO2 eq.]
EF 3.0 Climate Change, land use and land use change	1.63E+10	[kg CO2 eq.]
EF 3.0 Ecotoxicity, freshwater - total [CTUe]	3.06E+12	[CTUe]
EF 3.0 Ecotoxicity, freshwater inorganics [CTUe]	8.55E+11	[CTUe]
EF 3.0 Ecotoxicity, freshwater metals	1.90E+12	[CTUe]
EF 3.0 Ecotoxicity, freshwater organics	3.16E+11	[CTUe]
EF 3.0 Eutrophication, freshwater	2.69E+07	[kg P eq.]
EF 3.0 Eutrophication, marine	1.89E+08	[kg N eq.]
EF 3.0 Eutrophication, terrestrial	1.04E+09	[Mole of N eq.]
EF 3.0 Human toxicity, cancer - total	3.96E+03	[CTUh]
EF 3.0 Human toxicity, cancer inorganics	3.53E-09	[CTUh]
EF 3.0 Human toxicity, cancer metals	3.89E+03	[CTUh]
EF 3.0 Human toxicity, cancer organics	5.81E+01	[CTUh]
EF 3.0 Human toxicity, non-cancer - total	1.69E+03	[CTUh]
EF 3.0 Human toxicity, non-cancer inorganics	2.29E+02	[CTUh]
EF 3.0 Human toxicity, non-cancer metals	1.37E+03	[CTUh]

INDICATOR	Value	Reference Unit
EF 3.0 Human toxicity, non-cancer organics	1.04E+02	[CTUh]
EF 3.0 Ionising radiation, human health	1.02E+10	[kBq U235 eq.]
EF 3.0 Land Use	1.23E+12	[Pt]
EF 3.0 Ozone depletion	7.31E+03	[kg CFC-11 eq.]
EF 3.0 Particulate matter	6.34E+03	[Disease incidences]
EF 3.0 Photochemical ozone formation, human health	2.99E+08	[kg NMVOC eq.]
EF 3.0 Resource use, fossils	2.11E+12	[MJ]
EF 3.0 Resource use, mineral and metals	4.09E+07	[kg Sb eq.]
EF 3.0 Water use	1.25E+11	[m³ world equiv.]

NOTES

NOTES

Flainox S.r.l.
Via Leopardi, 5
13854 Quaregna (Biella)
+39 015 980680
info@flainox.com
www.flainox.com