LCA OF NRG 180 DYEING MACHINE

In collaboration with

D'APPOLONIA

consulting, design, operation & maintenance engineering

the innovation consulting partner

Goal of the study

The application of the study is to assess the energetic and environmental impacts of NRG Universal machine along the entire life cycle, comparing standard and innovative predefined processes. 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 section.

Three machines are object of the analysis:

- NRG Standard
- NRG Innovative – 2013 Version
- NRG Innovative – 2015 Version

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

<u>WHAT IS AN LCA?</u>
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 method, 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 14044:2006 and ISO 14040:2006) main requirements that identifies a series of steps, i.e.: 1. LCA goal & scope definition 2. Inventory analysis (LCI) 3. Impact assessment (LCIA) 4. Interpretation

Scope of the study

Several considerations and assumptions were made in order to define the details of the model to be developed. The scope of this study is to provide data to evaluate sustainability performances of NRG Universal FLAINOX in a cradle to grave analysis.

As a result, the LCA considers the relevant phases of the life cycle of the product, i.e. the cradle-to grave concept: the analysis starts with the extraction of raw materials, materials and components' production from different suppliers located in several geographical areas. The components are then further processed in FLAINOX facilities in Quaregna (BI). Moreover the LCA approach covers all manufacturing operations, performed in function of the final objective, the sale of dyeing machine to a textile company and its following operational life. The analysis covers also the disposal/re-use/recycling of all elements both generated during the production and use phases: all these phases will be accounted. This will be possible thanks to information provided by FLAINOX to LCA practitioners.

Function, functional unit and reference flow

The entire life cycle of NRG Universal 180 since raw materials providing until final dismantling, through manufacturing and use phases (able to perform 49625 cycles), has been adopted as the functional unit: the NRG Universal with a mass of around 5007 kg and a useful lifetime of 20 years. The choice is useful for simplifying data elaboration and the understanding of the different involved processes. 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 Universal 240 and NRG Universal 90 are going to be assessed, through a conversion table created from NRG 180 results.

The NRG is a rotary machine for the dyeing of garments, hosiery and seamless, manufactured in Quaregna, Biella, Italy and exported as final product all over the world. Flainox in fact has a wide customer network in Asia, Africa and America.

Also the dismantling phases will be assessed, taking into account that three options are possible:

- dismantling on site;
- return to Flainox and dismantling in its facilities;
- sale of machine to a third part, losing the control of the machine itself.

Modelling framework

Given the previously defined goal and scope and following the rules provided under ISO 14044:2006, a Life Cycle Impact Assessment has to be carried out.

In the analysis considering that preliminary results affirmed that use phase weights over 99% of total life cycle, the manufacturing processes for machine have been considered equal for standard and innovative products (both 2013 version and 2015 one).

Besides after production chain, the operation of machine, which takes place in a define textile dyeing company, have to be taken into account, in order to have the widest vision of the machine life cycle and considering that it covers almost the global impact of life cycle.

System boundaries

The LCA is conducted on "Cradle to Grave" basis. The production, the use (maintenance and operation) and end-of-life phase for the NRG universal machine is taken into account.

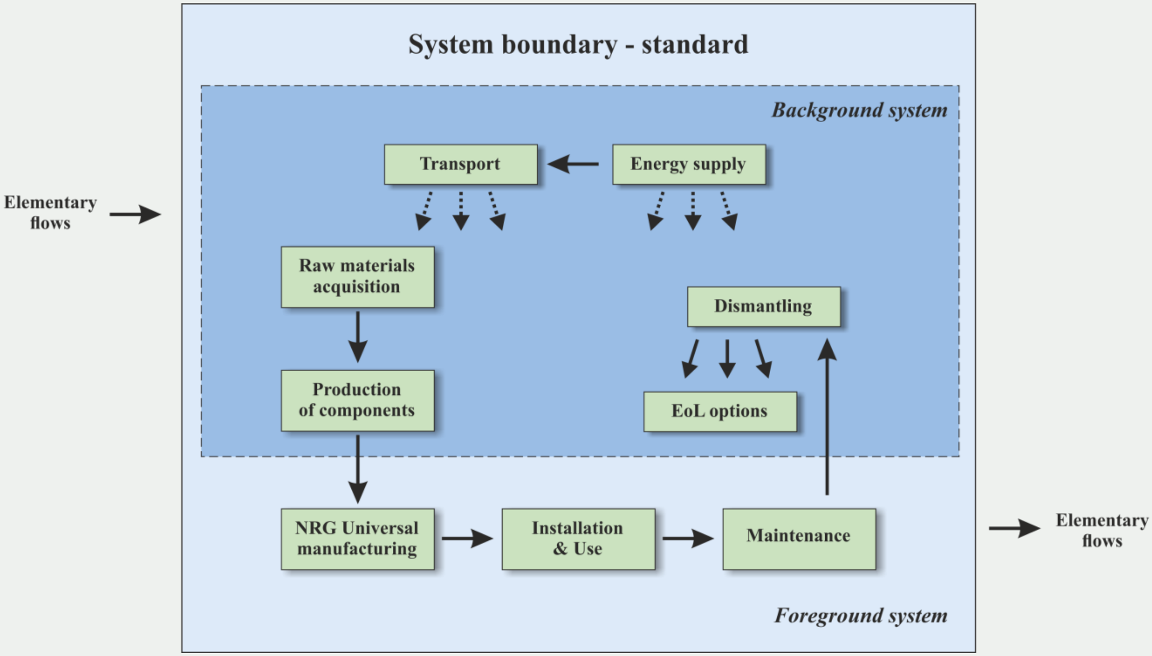
Temporal boundaries shall be taken into account, because the process of production of single components is characterized by different times.

After that there are the use phase and maintenance operations. The reference cycle, used also for evaluation of consumptions, is realized in an European factory: so the chosen location for installation is Europe, but of course Flainox NRG machines are purchased, installed and used also outside Europe, mainly Africa and Asia. The expected lifetime is 20 years.

All the phases last different periods: it could be assumed that the entire cycle until installation is covered in 1 year. These assessments 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.

Instead for the definition of geographic borders it is important to notice that it covers Europe, as previously defined and in accordance with reference cycle used for calculations, which is performed by a European factory. The NRG 180 is also sold to non-European customers.

Figure below schematically depicts the steps considered in the analysis and is valid for the both products. Raw materials are extracted and processed before reaching the mills 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.



LCA General Model with Boundaries and Flows

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 processes. 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 6.

The five main phases of NRG machine are:

- raw materials purchase (same for three NRG 180 versions);
- assembly and manufacturing operations (same for three NRG 180 versions);
- transport to customer (same for three NRG 180 versions);
- use phase (different for three NRG 180 versions);
- dismantling (according to the three analysed options, same for three NRG 180 versions).

For each one of them, through collected data, a plan on GaBi 6 has been created, considering the three different processes, standard and innovative.

The NRG 180 is a rotary machine for dyeing and centrifuging of garments sock and seamless, which is available in several configurations according to the specific customer requests.

NRG 180

NRG 180 – Technical Data

Nominal Load		kg	180
Number of compartments		n.	3
Usable drum volume		m^3	3
Average power absorbed		kW	14
Peripheral speed during centrifuge		m/s	42
Machine width and depth		mm	3250
			1980
Total height		mm	2880
Weight	**Machine**	kg	3146
	Basket	kg	905
	Service group	kg	657
	Electrical panel	kg	300
Max working temperature at sea-level		°C	98

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

So a standard reference cycle does not exist and in the following LCA analysis, the practitioners have performed the assessment based on a specific process defined by one of Flainox customers. Each customer can tune the machine according specific requirements.

In the study some boundary conditions have been set in order to evaluate same cycle performed by different machine versions. Results will be provided within this framework; if boundary conditions will change, models and results should be revised.

In detail all the energy and material consumptions for use phase will be referred to NRG 180 machine used for dyeing 150 kg of polyamide stockings in blue/black.

The standard and innovative cycles will be compared in terms of processes and relative consumptions, across the 20 years of useful lifetime.

The standard process has a minimum water level of 3000 litres of water for NRG 180 (levels with wet material), against the innovative process – 2013 which is characterized by a minimum water level of 750 litres of water for NRG 180 (levels with wet material) and the innovative process – 2015 with a minimum water level of 400 litres of water for NRG 180 (levels with wet material). Standard process takes 3,5 hours to complete the cycle, against 3,25 hours of innovative processes. So considering 7 working days per week and 48 working weeks per year, standard machine will perform 46080 cycles against 49625 of the innovative ones. In conclusion to perform the same number of cycles, taking as reference the innovative machines, 1,08 standard machines are needed to have 49625 cycles.

The other life cycle steps have been accounted but they have been considered equal for both solutions:

- manufacturing;
- assembly;
- transport;
- maintenance;
- End of Life.

After the comparison between three processes realized inside NRG 180, through normalization factors, the results have been extended to NRG 90 and NRG 240.

For these two machines, the goal of the system is the same (dyeing polyamide 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. There are different methods that can be used to perform a LCIA.

Impact category	***Units***
Global Warming Potential	[kg CO_2-Equiv.]
Ozone Depletion Potential	[kg CFC 11-Equiv.]
Particulate/matter respiratory inorganics	[kg PM 2,5 Equiv.]
Acidification Potential	[mol H+ - Equiv.]
Resource depletion, mineral fossil	[kg Sb. – Equiv.]
Ecotoxicity	[CTUe]
Human Toxicity (carcinogenic)	[CTUh]
Human Toxicity (non-carcinogenic)	[CTUh]
Ionizing Radiation	[kg U235 eq]
Photochemical Ozone Creation Potential	[kg NMOVC.]
Eutrophication Potential (EP) – freshwater and marine	[kg P/N - Equiv.]
Water depletion	kg
Terrestrial Eutrophication	[mol N - Equiv.]
Primary energy demand from ren. and non ren. Resources	MJ

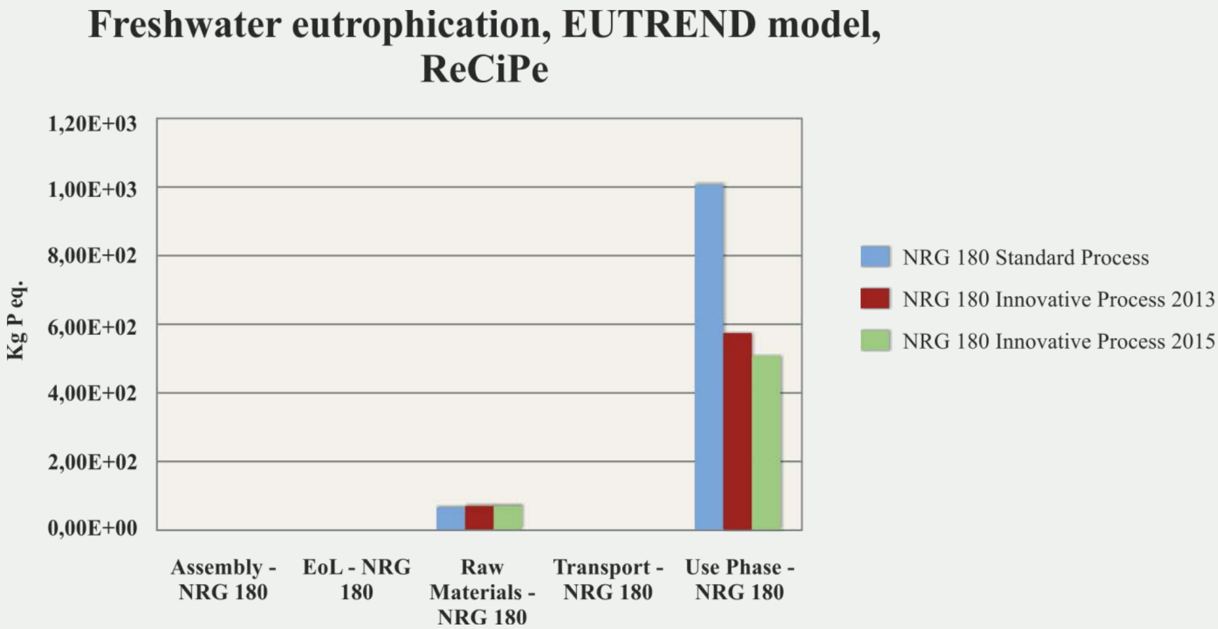
Analysing the results some considerations can be done:

- the reduction is evident both comparing Standard Life Cycle with Innovative 2015 Life Cycle, and Innovative 2013 Life Cycle with Innovative 2015 Life Cycle. This decrease shows the **persistent efforts** which Flainox is performing for **pursuing the continuous reduction of environmental impacts of their machines**;
- globally the **innovative process of 2015** (considering equal in terms of absolute values the other phases) generates a benefit compared both to innovative process of 2013 and to standard process. These benefits (calculated for the entire machine life cycles) vary from a **reduction of 13% for Resource Depletion** compared to standard (2% compared to innovative 2013) until a reduction of **over 80% for Water Footprint** compared to standard (41% to innovative 2013). The reduction are so due to technological implementations brought in terms of machine design and setting optimization which generate a reduction in terms of use of water, energies and chemicals;
- the contribution of use phase, compared to other ones is evident and it overcomes the 90% (often the 99%) in almost the indicators. Only for Ecotoxicity and Resource Depletion the raw materials are responsible for over around the 20% of total value (the use of steel materials in manufacturing operations is the main responsible).

Results Comparison

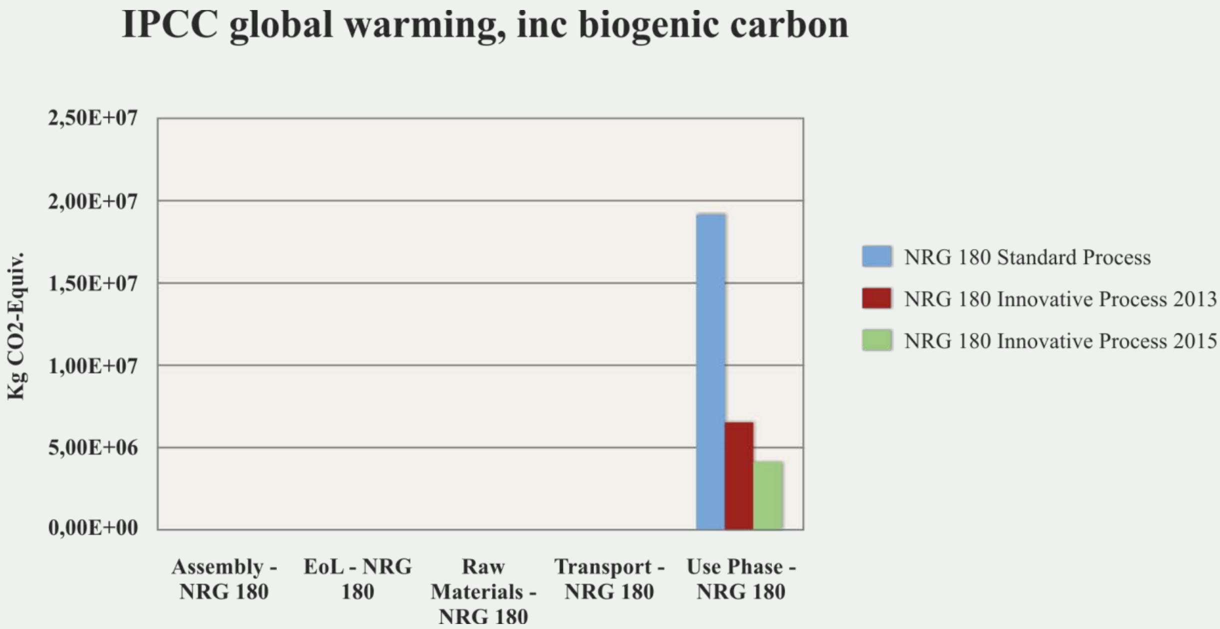
In order to have a more detailed view of the results, some bar charts, starting from previous results have been created. In particular the next analysis is focused on **six indicators**:

- **Freshwater eutrophication**, due to the high amount of water used it is necessary evaluate the benefit due the reduction of this source in new process especially focus on the effects of waste water into environment;
- **Global Warming Potential** – Carbon Footprint which is usually one of the most easy to understand indicators and it evaluate the emission of greenhouses gases;
- **Ozone Depletion** in order to evaluate the burdens on ozone hole effect;
- **Resource Depletion** which is one of the two indicators where Raw Materials have a noticeable impact;
- **Freshwater consumption** – Water Footprint due to the use of high amount of water for operations;
- **Primary Energy Demand** which evaluated the Gross Energy Requirements along the entire systems life cycles.



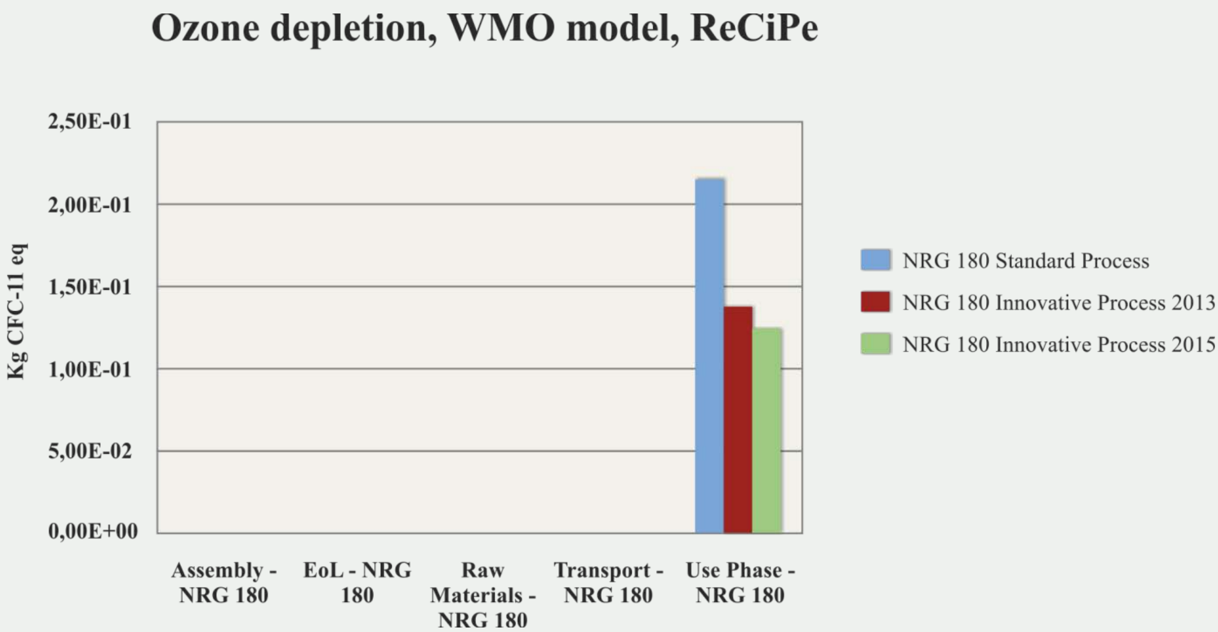
Freshwater Eutrophication – Phases Comparison

Use phase is the main contributor. There is a reduction of around 47% from standard to innovative process 2015 (use phase) and of 11% from innovative process of 2013 to innovative process of 2015. Absolute values of raw materials impacts still remain the same, except the increase of standard column due to the slower dyeing cycle, which requires 1,08 machines for performing 49625 cycles (as stated in functional unit).



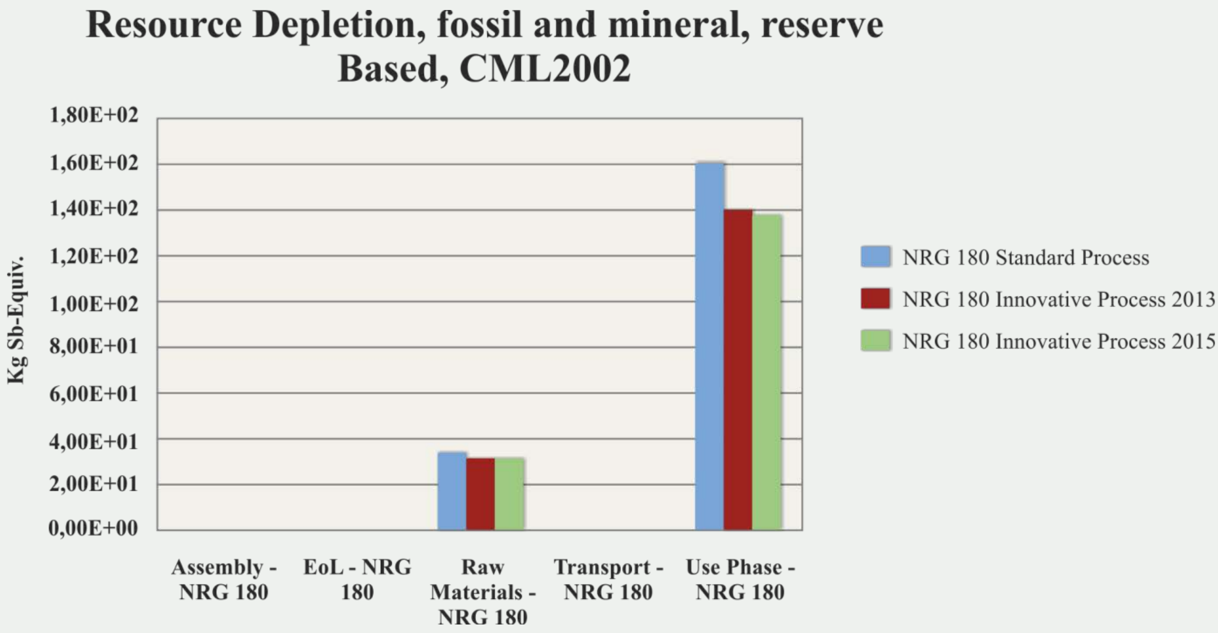
Global Warming Potential – Phases Comparison

Decreases of 79% from standard and one of 41% from innovative process 2013 to innovative process 2015 are present in use phase impacts for carbon footprint. Other contributions are negligible.



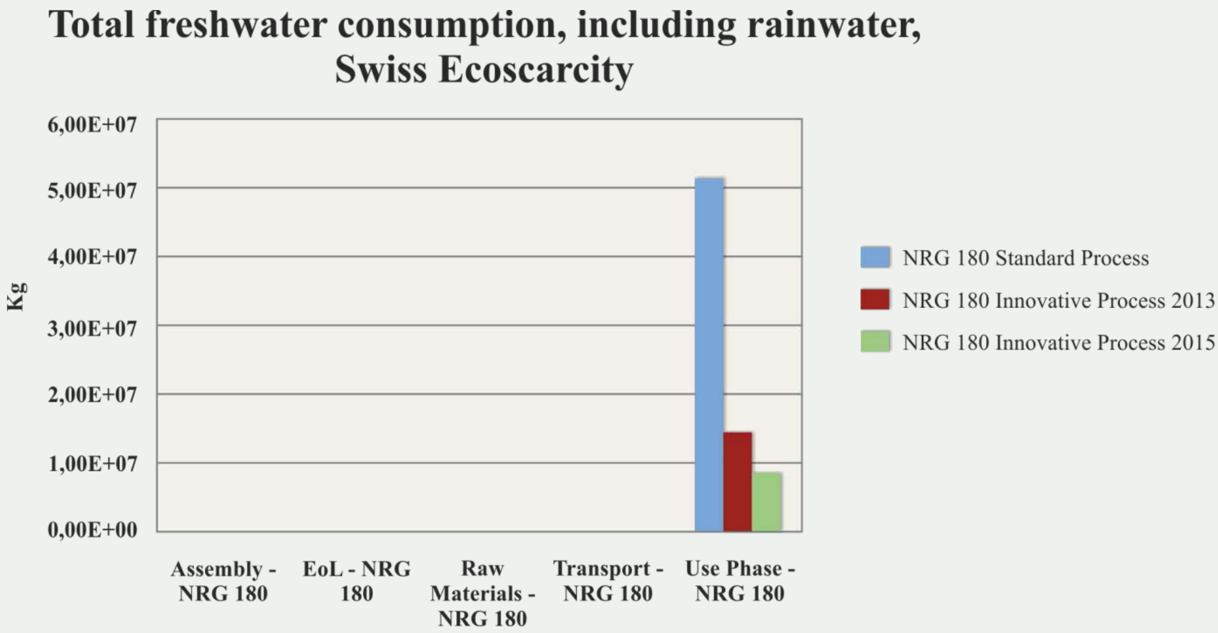
Ozone Depletion – Phases Comparison

The only evident contributor is the use phase. Passing from old to new process there is a reduction of respectively around 40% (compared to standard) and 8% (compared to innovative 2013).



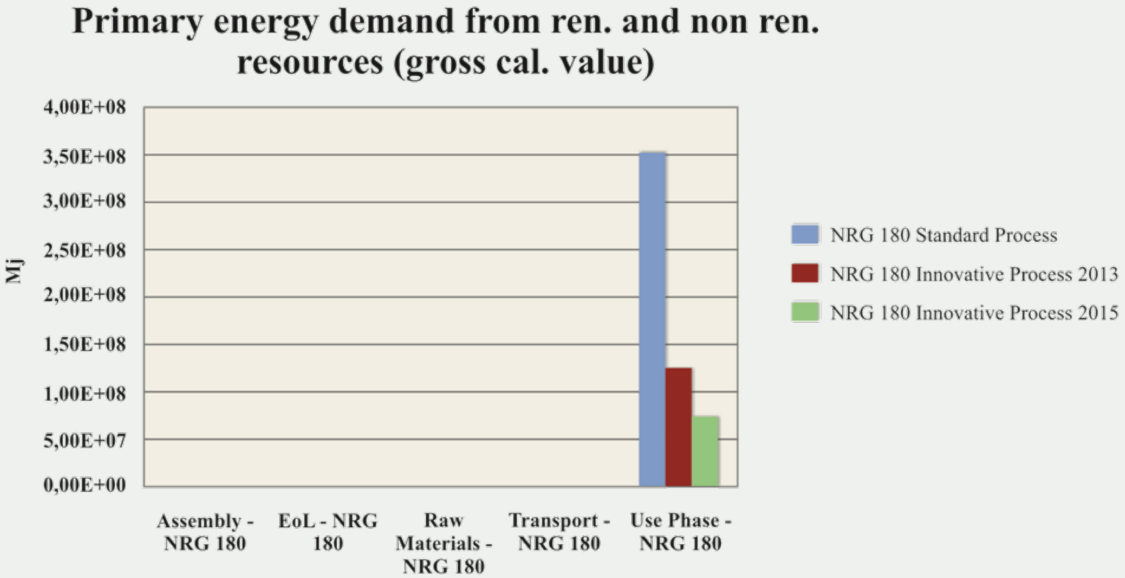
Resource Depletion – Phases Comparison

As regards Resource Depletion the benefit of new dyeing process is partially weakened by the raw materials contribution. A reduction is of course present but with a percentage referred to use phase of only 13% (Innovative 2015 vs. Standard) and 2% (Innovative 2015 vs. Innovative 2013).



Freshwater Consumption – Phases Comparison

The benefits of the new dyeing process are very high also in water footprint. The complete reduction is over 83% (compared to standard process realised for 20 years), with a reduction of 41% due to technological implementations performed from 2013 to 2015. There is a correspondent benefit also on eutrophication: less water consumed implies less water to wastewater treatment plant.



Primary Energy Demand – Phases Comparison

Finally also for use phase it is important the benefit due to the new process with a reduced minimum water level for dyeing process, that implies a reduction of thermal energy. In use phase the reduction of this indicator is around 79% (Standard vs. Innovative 2015) and 40% (Innovative 2013 vs. Innovative 2015).

CONCLUSIONS

This LCA study has been performed by D'Appolonia in accordance with main requirements of international standards (ISO 14040:2006 and 14044:2006) and internationally recognized guidelines (i.e., ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance).

The report provides indications on the environmental footprint on one of the main products of Flainox catalogue, the NRG 180. The benefits linked to the introduction of a new process have been evaluated and are evident, starting from the premise that the use phase in such kind of machine has an impact much higher than other life cycle phases.

As references, two different cycles have been used: the standard one and the innovative developed in 2013. Starting from these ones, the Company has further worked on enhancing dyeing process in terms of environmental performances, with the result of a new Innovative Process in 2015.

Globally the **innovative process set in 2015** (considering equal in terms of absolute values the other phases) generates noticeable benefits compared to standard process. These benefits (calculated for the entire machine life cycles) vary from a **reduction of 13% for Resource Depletion** until a reduction of **over 80% for Water Footprint**. The benefits are evident also comparing results of 2015 with results of 2013: a reduction of 2% for Resource Depletion until 41% for Water and Carbon Footprint.

The positive results achieved through the introduction of the new process show the great attention of Flainox to the issue of the environmental sustainability.

Indeed, the Policy of the company is oriented towards a continuous reduction of the environmental impacts generated by its dyeing machines.

80% decreasing of the Water Footprint is extremely significant, considering the cost and the possible shortage of water.

In fact, the reduction of the amount of water consumed during the process means a consequent reduction of the quantities of chemicals and thermal energy involved.

Moreover, the above mentioned reduction results in savings of the operational costs of the dyeing process. These benefits are not only for Flainox, but also for the user of the machinery and the local community, since it permits to save water that can be utilized for other uses, other than the dyeing ones, and less waste water needs to be treated before being released into environment.

References

DG JRC/IES, ILCD Handbook, 2011.

Ecoinvent Converted ecoinvent 1.01 data as unit processes with links to other processes, including uncertainty data, The Swiss centre for Life Cycle Inventories, 2000.

Flainox, Internal Documentation related to materials and energy consumptions, waste produced, 2013 [D’Appolonia Internal Reference: 13-409-G1].

Flainox, Internal Documentation on Machine Consumptions, 2013 [D’Appolonia Internal Reference: 13-409-G9 and G10].

Flainox, Internal Documentation on Machine Consumptions, 2015 [D’Appolonia Internal Reference: 15-522-G1 and G2].

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 operational 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.

ISO 14040:2006, Environmental management -- Life cycle assessment -- Principles and framework, 2006.

ISO 14044:2006, Environmental management -- Life cycle assessment -- Requirements and guidelines, 2006.

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 90 and NRG 240

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

The Use Phase (both standard and innovative) is the main impacting one and the results for standard and innovative NRG 180 processes (49625 cycles) have been converted for NRG 90 and NRG 240, through the following factors:

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

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

INDICATOR	NRG 90			Reference Unit
	Standard	Innovative 2013	Innovative 2015	
Acidification, accumulated exceedance	2,634E+04	1,117E+04	8,424E+03	[Moles of H+-Equiv.]
Ecotoxicity for aquatic fresh water, USEtox	6,540E+06	3,702E+06	3,257E+06	[CTUe]
Freshwater eutrophication, EUTREND model, ReCiPe	4,782E+02	2,720E+02	2,398E+02	[kg P eq]
Human toxicity cancer effects, USEtox	1,708E-01	8,241E-02	6,862E-02	[CTUh]
Human toxicity non-canc. effects, USEtox	6,744E-01	2,941E-01	2,344E-01	[CTUh]
Ionising radiation, human health effect model, ReCiPe	1,420E+08	9,190E+07	8,412E+07	[kg U235 eq]
IPCC global warming, incl biogenic carbon	9,097E+06	3,215E+06	1,903E+06	[kg CO2-Equiv.]

INDICATOR	NRG 90			Reference Unit
	Standard	Innovative 2013	Innovative 2015	
Marine eutrophication, EUTREND model, ReCiPe	1,277E+03	4,970E+02	3,631E+02	[kg N-Equiv.]
Ozone depletion, WMO model, ReCiPe	1,008E-01	6,553E-02	6,004E-02	[kg CFC-11 eq]
Particulate matter/Respiratory inorganics, RiskPoll	2,246E+03	9,273E+02	7,035E+02	[kg PM2,5-Equiv.]
Photochemical ozone formation, LOTOS-EUROS model, ReCiPe	1,955E+04	6,734E+03	4,357E+03	[kg NMVOC]
Resource Depletion, fossil and mineral, reserve Based, CML2002	7,586E+01	6,661E+01	6,509E+01	[kg Sb-Equiv.]
Terrestrial eutrophication, accumulated exceedance	7,428E+04	2,665E+04	1,798E+04	[Mole of N eq.]
Total freshwater consumption, including rainwater, Swiss Ecoscarcity	2,425E+07	6,831E+06	4,023E+06	[kg]
Primary energy demand from ren. and non ren. resources (gross cal. value)	1,665E+08	5,922E+07	3,539E+07	[MJ]

INDICATOR	NRG 240			Reference Unit
	Standard	Innovative 2013	Innovative 2015	
Acidification, accumulated exceedance	7,567E+04	3,208E+04	2,420E+04	[Moles of H+-Equiv.]
Ecotoxicity for aquatic fresh water, USEtox	1,879E+07	1,063E+07	9,356E+06	[CTUe]
Freshwater eutrophication, EUTREND model, ReCiPe	1,374E+03	7,813E+02	6,888E+02	[kg P eq]
Human toxicity cancer effects, USEtox	4,907E-01	2,367E-01	1,971E-01	[CTUh]
Human toxicity non-canc. effects, USEtox	1,937E+00	8,448E-01	6,732E-01	[CTUh]
Ionising radiation, human health effect model, ReCiPe	4,078E+08	2,640E+08	2,416E+08	[kg U235 eq]
IPCC global warming, incl biogenic carbon	2,613E+07	9,234E+06	5,467E+06	[kg CO2-Equiv.]
Marine eutrophication, EUTREND model, ReCiPe	3,669E+03	1,428E+03	1,043E+03	[kg N-Equiv.]
Ozone depletion, WMO model, ReCiPe	2,896E-01	1,882E-01	1,725E-01	[kg CFC-11 eq]
Particulate matter/Respiratory inorganics, RiskPoll	6,452E+03	2,663E+03	2,021E+03	[kg PM2,5-Equiv.]
Photochemical ozone formation, LOTOS-EUROS model, ReCiPe	5,617E+04	1,934E+04	1,252E+04	[kg NMVOC]

INDICATOR	NRG 240			Reference Unit
	Standard	Innovative 2013	Innovative 2015	
Resource Depletion, fossil and mineral, reserve Based, CML2002	2,179E+02	1,913E+02	1,870E+02	[kg Sb-Equiv.]
Terrestrial eutrophication, accumulated exceedance	2,134E+05	7,656E+04	5,165E+04	[Mole of N eq.]
Total freshwater consumption, including rainwater, Swiss Ecoscarcity	6,966E+07	1,962E+07	1,156E+07	[kg]
Primary energy demand from ren. and non ren. resources (gross cal. value)	4,781E+08	1,701E+08	1,017E+08	[MJ]

NOTES

NOTES

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