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FLAINOX
Quaregna (BI), Italy

Life Cycle Assessment

D.2 LCA of NRG Universal Equipment, Manufactured by FLAINOX – Executive Summary

D'APPOLONIA
consulting design operation & maintenance engineering

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Quaregna (BI), Italy

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LIFE CYCLE ASSESSMENT

1 INTRODUCTION

The present document constitutes Deliverable D2 "LCA of NRG Universal equipment, manufactured by FLAINOX – Executive Summary" in the framework of the project entitled "Life Cycle Assessment" (Doc.No. 13-409 D1).

1.1 LCA METHODOLOGY

In the present Report the results of the LCA (Life Cycle Assessment) carried out for the process systems are documented.

A life-cycle approach takes into consideration the spectrum of resource flows and environmental interventions associated with a product or organisation from a supply-chain perspective. It includes all stages from raw material acquisition through processing, distribution, use, and end-of-life processes, and all relevant related environmental impacts, health effects, resource-related threats, burdens to society, and trade-offs. Such an approach is essential to effective management because important environmental effects may occur "upstream" or "downstream", and hence may not be immediately evident. This approach is also essential for making transparent any potential trade-offs between different types of environmental impacts associated with specific policy and management decisions and to help avoid unintended shifting of burdens.

Life Cycle Assessment is therefore a vital and powerful decision support tool, complementing other methods, which are equally necessary to help effectively and efficiently make consumptions and production more sustainable.

This LCA study has been performed in accordance with internationally recognized guidelines (see e.g. ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance") and standard (ISO 14044:2006) main requirements.

In addition the Recommendations 2013/179/EU "Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations" has been used as further reference in developing the assessment for Product Environmental Footprint (PEF).

The Product Environmental Footprint (PEF) is a multi-criteria measure of the environmental performance of a good or service throughout its life cycle. PEF information is produced for the overarching purpose of seeking to reduce the environmental impacts of goods and services taking into account supply chain activities (from extraction of raw materials, through production and use, to final waste management). The PEF methodology provides a method for modelling the environmental impacts of the flows of material/energy and the emissions and waste streams associated with a product throughout its life cycle.

The LCA of Flainox NRG 180 machine has been conducted and here an executive summary is presented.

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2 DESCRIPTION OF THE MAIN PRODUCT MANUFACTURING (FOREGROUND)

The analysis is focused on the comparison between two versions of the NRG 180 machines manufactured and commercialized by Flainox, company specialized in the manufacturing of dyeing and finishing machineries.

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

Figure 2.1: NRG – 180

The machines can be tuned by customers according 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 customer.

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 15 years of useful lifetime.

The standard process has a liquor ratio (l/kg) of 1:20, against the innovative process which is characterized by a liquor ratio of 1:5. Standard process takes 3,5 hours to complete the cycle, against 3,25 hours of innovative process. So considering 7 working days per week and 48 working weeks per year, standard machine will perform 34560 cycles against 37218 of the innovative one. In conclusion to perform the same number of cycles, taking as reference the innovative machine, 1,08 standard machines are needed to have 37218 cycles.

3 GOAL OF THE STUDY

3.1 INTENDED APPLICATION(S)

The application is to assess the energetic and environmental impacts of NRG 180 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 scope settings.

In addition results obtained through a proportion, are provided also for NRG 90 and NRG 240.

3.2 REASONS FOR CARRYING OUT THE STUDY AND DECISION-CONTEXT

The intended application is to provide product information about environmental performances to Flainox: in this work LCA does not support any kind of decision.

	YES	NOT
This LCI/LCA study is utilized to support a decision by the Client		X
The LCI / LCA study is interested in the potential changes of this decision		X

3.3 DECISION SUPPORT

<table>
<tr><td rowspan="4">Decision support?</td><td rowspan="3">Yes</td><td colspan="2">Kind of process-changes in background system / other systems</td></tr>
<tr><td>None or small-scale</td><td>Large-scale</td></tr>
<tr><td>Situation A
"Micro-level decision support"</td><td>Situation B
"Meso/macro-level decision support"</td></tr>
<tr><td>No</td><td colspan="2">Situation C
"Accounting"
(with C1: including interactions with other systems, C2: excluding interactions with other systems)</td></tr>
</table>

Situation A	
Situation B	
Situation C1	X
Situation C2	

3.4 TARGET AUDIENCES

The target audience of this study is FLAINOX personnel (mainly technical personnel, such R&D personnel); Flainox management is the Commissioner of the Study.

4 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 an cradle to grave analysis.

4.1 FUNCTIONAL UNIT

The entire life cycle of NRG Universal 180 since raw materials providing until final dismantling, through manufacturing and use phases (able to perform 37218 cycles), has been adopted as the functional unit: the NRG Universal with a mass of around 5007 kg and an useful lifetime of 15 years. In the use phase a defined and repeteable dyeing process has been assessed, according specific customer information provided to Flainox.

Inventory data are taken from either direct measurements or equipment data sheets.

The main sources for measurements have been:

- data provided directly from FLAINOX, due to its previous experience in LCA methodology application;
- measured provided to Flainox by its customer.

Any other assumption is justified inside the report, when present.

4.2 SYSTEM BOUNDARIES

Processes in the background system have not been inventoried with actual data from suppliers but included and evaluated on the basis of 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 specifications of a defined customer) and the dismantling options consumptions belong to foreground system.

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 an European factory. However Flainox NRG machines are purchased, installed and used also outside Europe, mainly Africa and Asia.

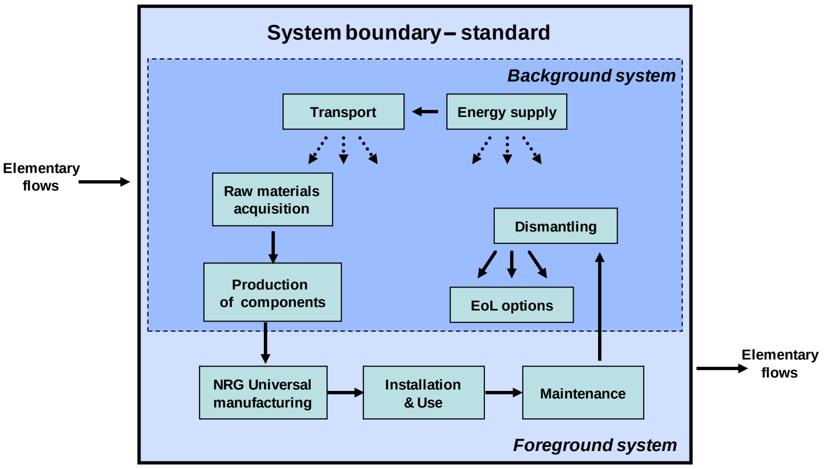

Figure 4.1: LCA General Model with Boundaries and Flows

4.3 LCIA SCOPE SETTINGS

The corresponding impact categories to be considered are in the following Table, according the recommendations of Product Environmental Footprint (2013/179/EU). In addition also the flow "Primary energy demand from renewable and non renewable resources (gross cal. value)" measured in MJ has been evaluated.

Impact category	Recommended Indicator mid-point	Chosen Indicator mid point
Acidification	The accumulated exceedence method of Seppälä et al. (Seppala, Posch et al. 2006) is recommended	(Acidification, accumulated exceedance) Mole H+ eq.
Climate Change	Global Warming Potential (IPCC 2007), 100 year perspective (IPCC 2007)	Climate Change (IPCC 2007, GWP100a) - kg CO2 eq.
Ecotoxicity	The USEtox model is the most advanced and complete indicator (Rosenbaum, Bachmann et al. 2008). However toxicity results are still highly uncertain.	USEtox 2008, Ecotoxicity – PAF (Potentially Affected Fraction) CTUe
Eutrophication	The ReCiPe method is most advanced with respect to aquatic fate modeling and therefore recommended	Recipe – Freshwater/ Marine eutrophication, Eutrend Model - kg P/N eq.
Human Toxicity	The USEtox model is the most advanced and complete indicator (Rosenbaum, Bachmann et al. 2008). However toxicity results are still highly uncertain and indoor toxicity (at the production site) is not considered	Human Toxicity (USEtox, Human toxicity – carcinogenic and non-carginogenic) - CTUh
Ionizing radiation	The method of Frischknecht et al. (Frischknecht 2000) includes all vital model elements in sound way and is well documented	Ionizing Radiation (ILCD 2011 midpoint, Ionizing radiation - human health) kg U235 eq.
Land Use	The midpoint method implemented in ReCiPe simply adds up all land occupation and transformation. It is simple and robust, but misses environmental relevance (De Schryver and Goedkoop 2009)	Terrestrial eutrophication, accumulated exceedance [Mole of N eq.]
Resource depletion, fossil and mineral	This indicator expresses the cumulated non-renewable energy demanded to fulfill a certain function plus mineral depletion (Van Oers et al., 2002)	CML 2002 Resources Depletion, kg antimony-Eq
Ozone depletion	Latest WMO published ODP equivalents (currently WMO, 1999)	Ozone depletion (ILCD 2011 midpoint, Ozone depletion) - kg R11 eq.
Particulate matter/Respiratory inorganics	Risk Poll model (Humbert 2009)	Particulate matter/respiratory inorganics (kg PM2,5 eq.)
Photochemical ozone formation	The LOTOS-EUROS model as applied in the ReCiPe method for photochemical ozone formation (van Zelm, Huijbregts et al. 2008), consists of a detailed fate and exposure model for human health impacts and is developed in a form which makes it readily adaptable	Recipe – LOTUS-Euros model kg NMVOC
Water depletion	Several methods exist, ranging from inventory methods, scarcity indexes and mid-point indicators. Most approaches are still under development.	Total freshwater consumption, including rainwater, Swiss Ecoscarcity [kg]

5 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.

Processes in the background system have not been inventoried with actual data from suppliers but included and evaluated on the basis of data taken from the dedicated database of the software GaBi (PE, Ecoinvent mainly).

Processes in the foreground system have been instead inventoried based on data from the owner of the plant, i.e., Flainox and customers' feedbacks. Data have been collected thanks to wide availability shown by the Flainox management:

- directly measured by Flainox customer in the course of the years – this procedure mostly refers to data linked to use phases applies to most of the data in the foreground system;
- extracted from data sheets provided by suppliers and literature– this procedure mostly refers to parts under purchase;
- calculated based on specific formulas taken from literature – this procedure mostly refers to data conversion or estimated, based on experience of technicians – this procedure has been used when none of previous procedures was applicable and only applies to not relevant data.

The five main phases of NRG machine object of the analysis, are:

- raw materials purchase;
- assembly and manufacturing operations;
- transport to customer;
- use phase;
- dismantling (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).

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

5.1.1 NRG Universal 180 – LCI Model

The LCI model has been schematically represented by block flow diagrams where each block represents either a gate to gate process or a cradle to gate process or a partly linked/terminated process and is connected to upstream and/or downstream blocks by means of arrows representing input and/or output flows, respectively.

Schematic representations of the NRG 180 standard and innovative life cycles, including all main phases, have been created and reported in full version of report.

Calculation procedures are embedded in the GaBi6 software and in calculation sheet developed by D'Appolonia. They are available on request in case of LCA review.

6 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.

6.1 GLOBAL RESULTS

In the Table 6.1 the main results of the analysis are presented. In the full version report results also for Use phases of NRG 90 and NRG 240 are presented (assuming equal manufacturing and End-Of-Life phase).

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: 1,36).

Table 6.1: Global Impact Indicators

INDICATOR	Standard	Innovative	Var. [%]	Reference Unit
Acidification, accumulated exceedance	4,10E+04	1,76E+04	-56,96%	[Moles of H+-Equiv.]
Ecotoxicity for aquatic fresh water, USEtox	1,26E+07	7,92E+06	-37,16%	[CTUe]
Freshwater eutrophication, EUTREND model, ReCiPe	8,29E+02	4,95E+02	-40,28%	[kg P eq]
Human toxicity cancer effects, USEtox	2,80E-01	1,38E-01	-50,56%	[CTUh]
Human toxicity non-canc. effects, USEtox	1,17E+00	5,60E-01	-52,26%	[CTUh]
Ionising radiation, human health effect model, ReCiPe	2,33E+08	1,53E+08	-34,42%	[kg U235 eq]
IPCC global warming, incl biogenic carbon	1,34E+07	4,79E+06	-64,16%	[kg CO2-Equiv.]
Marine eutrophication, EUTREND model, ReCiPe	2,01E+03	7,92E+02	-60,64%	[kg N-Equiv.]
Ozone depletion, WMO model, ReCiPe	1,63E-01	1,07E-01	-34,59%	[kg CFC-11 eq]
Particulate matter/Respiratory inorganics, RiskPoll	3,55E+03	1,49E+03	-58,11%	[kg PM2,5-Equiv.]
Photochemical ozone formation, LOTOS-EUROS model, ReCiPe	3,01E+04	1,05E+04	-65,21%	[kg NMVOC]
Resource Depletion, fossil and mineral, reserve Based, CML2002	1,53E+02	1,36E+02	-11,08%	[kg Sb-Equiv.]
Terrestrial eutrophication, accumulated exceedance	1,15E+05	4,17E+04	-63,76%	[Mole of N eq.]
Total freshwater consumption, including rainwater, Swiss Ecoscarcity	3,87E+07	1,09E+07	-71,79%	[kg]
Primary energy demand from ren. and non ren. resources (gross cal. value)	2,44E+08	8,82E+07	-63,93%	[MJ]

Analyzing the results some considerations can be done:

- globally **the innovative process** (considering equal in terms of absolute values the other phases) generates a benefit compared to standard process. These benefits (calculated for the entire machine life cycles) vary from a **reduction of 11% for Resource Depletion** until a reduction of **over 70% for Water Footprint**. The reduction are so due to technological implementations brought by a reduction in 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).

6.2 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 (Figure 6.1);
- **Global Warming Potential** – Carbon Footprint which is usually one of the most easy to understand indicators and it evaluate the emission of greenhouses gases (Figure 6.2);
- **Ozone Depletion** in order to evaluate the burdens on ozone hole effect (Figure 6.3);
- **Resource Depletion** which is one of the two indicators where Raw Materials have a noticeable impact (Figure 6.4);
- **Freshwater consumption** – Water Footprint due to the use of high amount of water for operations (Figure 6.5);
- **Primary Energy Demand** which evaluated the Gross Energy Requirements along the entire systems life cycles (Figure 6.6).

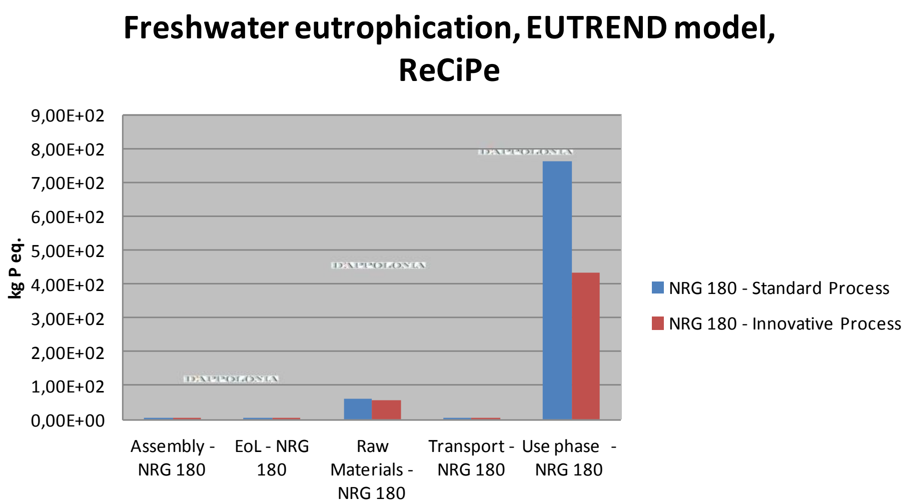

Figure 6.1: Freshwater Eutrophication – Phases Comparison

Use phase is the main contributor. There is a reduction of around 43% from standard to innovative processes (use phase). Absolute values of raw materials impacts still remain the same.

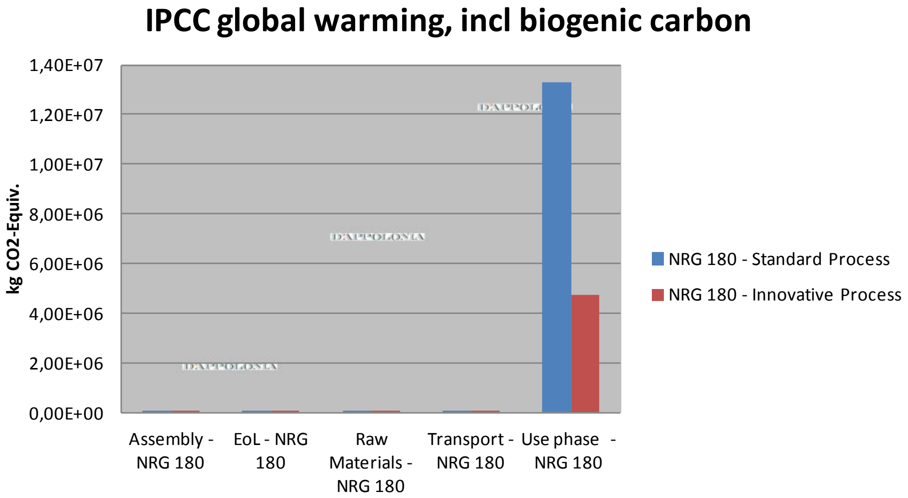

Figure 6.2: Global Warming Potential – Phases Comparison

A decrease of 64% from standard to innovative process is present in use phase impacts for carbon footprint. Other contributions are negligible.

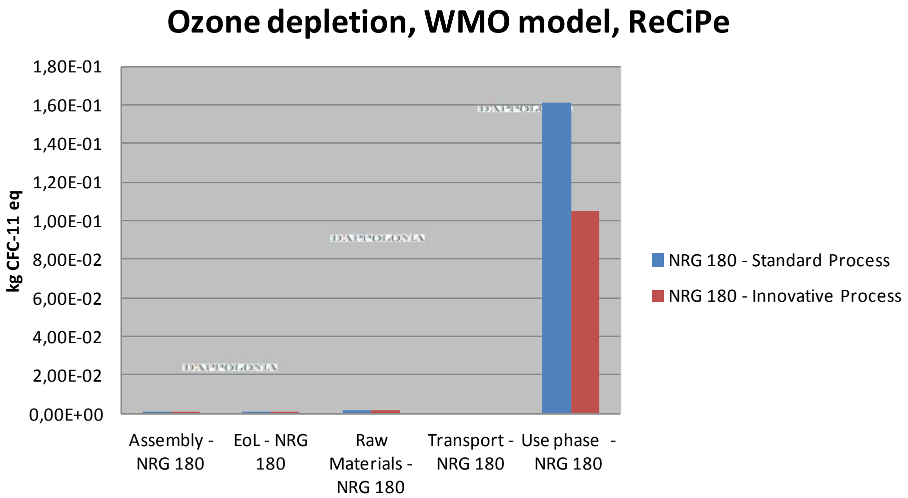

Figure 6.3: Ozone Depletion – Phases Comparison

The only evident contributor is the use phase. Passing from old to new process there is a reduction of around 35%.

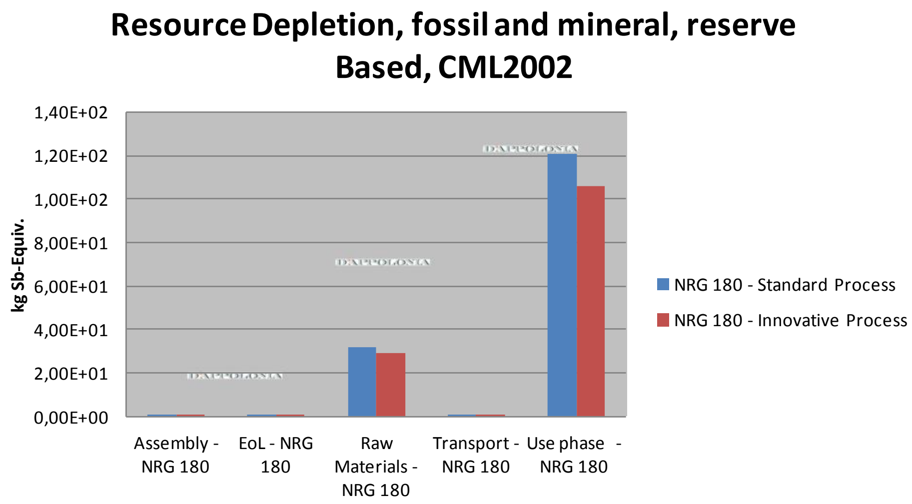

Figure 6.4: Resource Depletion – Phases Comparison

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 12%.

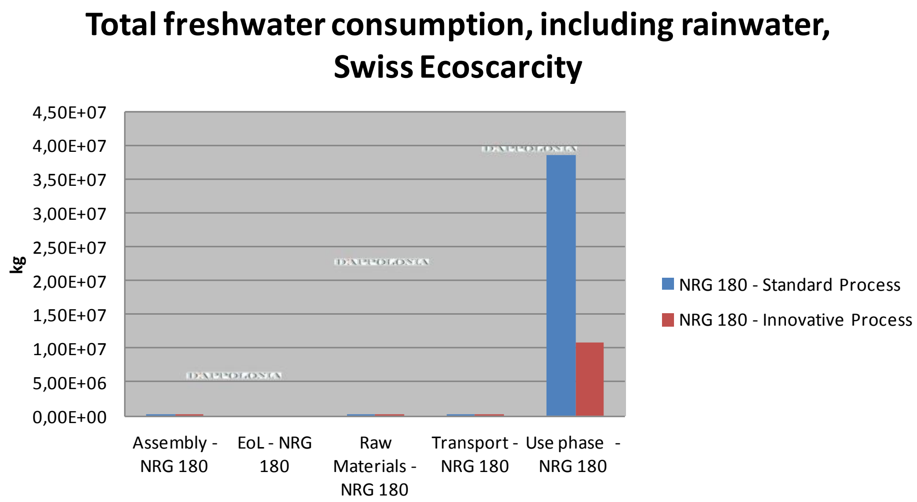

Figure 6.5: Freshwater Consumption – Phases Comparison

The benefit of the new dyeing process is very high also in water footprint. A reduction of over 70% is present, with correspondent benefit also on eutrophication: less water consumed implies less water to wastewater treatment plant.

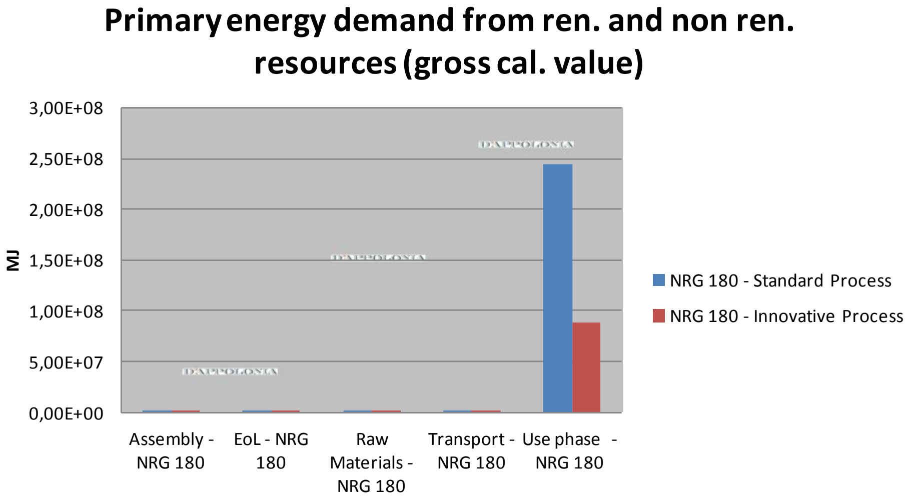

Figure 6.6: Primary Energy Demand – Phases Comparison

Finally also for use phase it is important the benefit due to the new process with a less liquor ratio, that implies a reduction of thermal energy. In use phase the reduction of this indicator is around 64%.

7 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 a such kind of machine has an impact much higher than other phases life cycle.

Globally the **innovative process** (considering equal in terms of absolute values the other phases) generates a benefit compared to standard process. These benefits vary from a reduction of 11% for Resource Depletion until a reduction of over 70% for Water Footprint.

The Water Footprint reduction has an immediate importance when the cost or the shortage of water overcomes other local factors.

Water reduction in the innovative process implies a direct reduction of chemicals and thermal energy, when comparing to the state of the art dyeing process.

Cutting water, chemicals and thermal energy consumptions means also a reduction of running costs of NRG 180 equipment.

This benefit is transferred to the user of the equipment and to the local community since water can be utilised for other uses, other than the dyeing ones.

Full version report provides detailed result on phases contributions and NRG 90 and NRG 240 machines.

MDS/GGU/PSA/RDL/DMZ:plp

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