Life Cycle Assessment of Galix 13 F1A and Green Galix

JOAKIM HÄGVALL AND ROLF TRYMAN

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Sammanfattning

Detta är den svenska slutrapporten av ett treårigt samarbetsprojekt med Frankrike. Projektets syfte har varit att undersöka om man med livscykelanalysmetoder kan förbättra ammunitions miljöprestanda. Till detta valdes rökkastarammunitionen Galix 13 F1A. Den svenska delen av detta projekt innebar att göra livscykelanalyser av ammunitionen och från detta bestämma kritiska faktorer för ammunitionens miljöprestanda. Utifrån detta skulle de franska partnerna designa en ny och förbättrad ammunition (kallad Green Galix). Sverige skulle efter detta verifiera att den nya designen hade bättre miljöprestanda.

Analysen visar att den nya designen har förbättrat miljöprestanda med ca 50%. Detta har till en del åstadkommits genom materialförbättringar men främst genom att ammunitionen har designats för att minimera miljöpåverkan. Den nya designen är anpassad för att kunna ta isär och återvinna ammunitionen . Detta har medfört att ammunitionen får en avsevärt förlängd livstid, från 8 år till 16 år.

Nyckelord: LCA, miljö, ammunition, Galix 13

Summary

This is the final Swedish report of a three year cooperation project with France. The project purpose has been to investigate whether it is possible to use life cycle methodology to improve the environmental performance of munitions. For this purpose the smoke munitions Galix 13 F1A was chosen.

The Swedish part of this project was to perform life cycle assessment of the munitions which would generate critical factors for the munitions environmental performance.

From these factors the French part would make a new munitions design (called Green Galix). Sweden would then evaluate the new design to find out whether the environmental performance actually had increased.

The assessment shows that the new design has improved the environmental performance about 50%. This has partly been achieved by small material changes and reductions, but the improvement comes mainly from the general design. The idea of the design is to minimize the environmental impact. This means that the munitions are made to come apart which makes it easy to reuse. This also extends the life of the munitions from 8 years to 16 years.

Keywords: LCA, Environment, munitions, Galix 13

Contents

1 Background

This report presents the work done by the Swedish part in a collaboration project between Sweden and France. The Swedish contribution to this cooperation was a Life Cycle Assessments (LCA) study of the munitions called Galix 13 F1A and to find environmental critical factors of the munitions. The French contribution was to on the basis of these factors construct new and environmentally improved munitions (this new munitions is called green Galix). Sweden would also confirm with LCA calculations whether the munitions environmental impact had improved with the new design.

The project started in November 2006 and was active for three years.

This report is a compilation of the Swedish LCA work (except education and training) within this project. This includes the final results from LCA for both Galix 13 F1A and the new design (Green Galix).

2 Methods

FOI has performed quantitative LCA´s using the computer program SimaPro 7.0 (www.pre.nl).

2.1 Constructing Life Cycle Inventory data

For some cases it is not easy to find satisfactory data for chemicals. However, a Swiss group has put forth a simplified method to calculate LCI data for chemical materials (Geisler et al., 2004). Since this study involves energetic materials and their component, and almost no data is available for these materials, the Swiss method was often used.

The Swiss group has built a structure of the Estimation Procedure based on Life Cycle Inventories (LCI). The LCI of any chemical product comprises a sequence of reactions used to synthesise the final product. In the estimation procedure lined out by the group, each reaction is assumed to be carried out in its own process step as long as no other information is available from the literature. The group has estimated two levels of impact, a best-case and a worst-case scenario. For these two cases they have estimated values for natural resources, need for solvents, energy demand and emission. Because some of the components are made in small quantities, by few manufacturers and in small specialised chemical factories, the worst-case scenario is used here to simplify the calculation.

Example

The first task is to investigate how these materials are manufactured. This is not always easy, but reference literature as Ullman's Encyclopaedia of Industrial Chemistry can be used. If no information is available in these kinds of reference works, Internet can be searched for information.

In the following example, it is shown how the emissions from the production of 1 kg of ammonium perchlorate were calculated

- ,The reaction formula for ammonium perchlorate (AP) was found in (Hägg 1964). .
- The chemical reaction for the production of ammonium perchlorate is described by $HClO_4 + NH_3 \rightarrow NH_4ClO_4$.
- The yield from the reaction is assumed by Geisler et al to be 0,87 (worst case), which means that 0,98 kg $HCLO_4$ and 0,17 kg NH_3 is used to produce 1 kg AP.
- The reaction take place in water and an estimated amount of 7 kg industrial water (PUR)/kg AP is needed, i.e. it results in 7 kg of wastewater.
- The natural resources that are needed to make 1 kg ammonium perchlorate is 730 kg of cooling water and 0.5 kg (0,4 Nm^3) Nitrogen. Resources from the techno sphere that are needed are 5,0 MJ of electricity and 7,7 kg of steam.

- Emission to air are estimated to 1,7 g ammonia (emission factor =0,001). Emission to water is assumed to be what is left from the reaction (materials not used due to the lower yield rate). which is estimated to 18,3 g of ammonia and 0,13 kg of perchloric acid, $HClO_4$.

2.2 Life cycle assessment

Life cycle assessment (LCA) is the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout the life cycle. Life cycle includes mining of raw material, production, use and disposal of a product (i.e. from cradle to grave) (ISO 14040, 1997). The term 'product' includes physical products as well as services. LCAs are often used for comparative studies. However, it is not the products that are compared, rather the function of the products.

The assessments are standardised in the ISO 14040- series (ISO, 1998; ISO, 2000a; ISO, 2000b; ISO, 1997), with a guide to the standards (Guinèe, 2003).

The analysis is performed in four phases, as described (according to Guinèe 2003) and illustrated below. During the process it can be necessary to go back to earlier phases to improve these.

Definition of goal and scope: The goal of the study should be explained, the intended use of the results, the initiator of the study, the practitioner, stakeholders and intended users of the results should be specified. A scope definition establishes the main characteristics of an intended LCA study, for example a technical or a geographical study. The function, functional unit alternatives and reference flows should be defined in this phase.

Inventory analysis: The product system is defined in the inventory analysis. The definition includes setting the system boundaries, designing the flow diagrams with unit processes, collecting data for each of these processes, performing allocation phases for multifunctional processes and completing the final calculations. The main result is an inventory table listing the quantified inputs and outputs to the environment associated with the functional unit, for example x kg carbon dioxide per studied product.

Impact assessment: The results from the inventory analysis are further processed and interpreted in the Life Cycle Impact Assessment (LCIA). This phase includes classification, characterisation and the optional phases normalisation, grouping and weighting. A list of impact categories is defined that is used to classify the results from the inventory analysis, on a purely qualitative basis. The actual modelling results are calculated in characterisation phase. The optional normalisation serves to indicate the share of modelled results to a reference, e.g. a worldwide or regional total. The results can be grouped and weighted to include societal preferences of the various impact categories.

Interpretation: The results from the analysis, all choices and assumptions made in the analysis are evaluated, in the interpretation, in terms of soundness and robustness. Conclusions are drawn and recommendations are made.

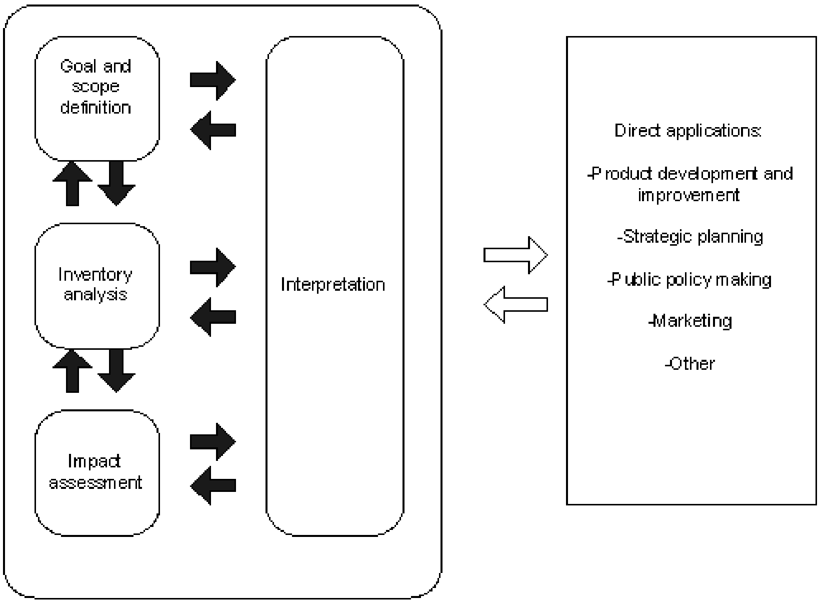


Figure 1, The framework for life cycle assessment, based on ISO 1997

Since LCAs focus on products, it is used for product development and improvement is important, as well as use in purchasing.

It is not possible to quantify everything, so qualitative data and estimations are therefore necessary to create a comprehensive picture even in a quantitative LCA. It is also possible to consider quantitative information in a qualitative LCA, when such is easily accessible (Johansson et al., 2001)

2.3 Overall methodological procedure

LCA is often described as an iterative process. The results presented in this report are results from several rounds of iterations using quantitative LCAs. The methodology for the quantitative LCA is largely based on the ISO standards (ISO, 1997, 1998, 1999, 2000 a,b) and the Dutch guide to the standards (Guinée, 2003). For calculations, the software program SimaPro 7.0 is used (PRé, 2001) complemented with databases from EcoInvent. In order to find LCI data for some specific materials, the procedure described above is used.

3 Goal and scope definition

3.1 Goal definition

During this study a comparative, descriptive assessment of one pallet of munitions items has been performed. This has been done on both the Galix 13 F1A and the new design (Green Galix).

The goals of this study are:

- To identify the critical functions in the life cycle which have the largest impact on the environment.
- To establish that the design changes is an improvement considering the environmental impact
- To increase the knowledge of Life cycle thinking and Ecodesign concerning munitions.

3.2 Scope definition

The scope of this study is, within practical limits, to do a quantitative LCA that includes all processes from cradle to grave (except the storage phase) for the Galix 13 F1A and for the new design (Green Galix).

In the study, the data used originates primarily from the producing country. If data from the producer country were unavailable, data were taken primarily from France and secondly from Sweden. In the case that there were no available data from those countries, any available data were used. Data were primarily taken from EcoInvent or SimaPro databases. EcoInvent is a database with the same format as the SimaPro database produced by the Swiss Centre for Life Cycle Inventories (www.ecoinvent.ch).

Ideally an LCA includes all products and processes in the munitions life. However, this is not always possible in practise. Some of the things that have been excluded in the LCA are:

- Storage
- The manufacturing of capital goods
- Support material for capital goods. This includes the manufacturing processes and the use phase of these goods.

Allocation problems encountered are of two types: multi-output and open-loop recycling allocation problems. The latter type has been solved by system expansion as recommended by the ISO standard (ISO 14041, 1998). Recycled materials are assumed to replace virgin materials. For some multi-output processes described below, all environmental impacts have been allocated to the main product. For many processes where data have been taken from databases, allocated data are used where different types of allocation approaches have been used.

Sometimes a distinction is made between consequential LCAs (which aim at modelling the consequences of a decision) and descriptive or accounting LCAs, which aims at describing a product system (e.g. Guinee et al, 2002, Tillman, 2000). This study is a descriptive study.

3.3 Functional unit

The functional unit is one pallet of munitions. In this case the functional unit is, 80 units/pallet both for the Galix 13 F1A and for the new design.

3.4 The LCA research team

A number of scientists have been involved in this LCA project. From Sweden two scientists from FOI took part, specialising in LCA and munitions. From France, several persons were involved specialized in the design and construction of this type of munitions from Nexter Munitions (Nexter) and Lacroix Pyrotechnics (Lacroix).

Besides these, a reference group were represented on all meetings. The reference group consisted of representatives from FMV (Sweden) and DGA-ETBS (France).

4 General information about the munitions

The GALIX system is mass produced and marketed jointly by NEXTER Munitions and Etienne Lacroix tous artifices. It is in service on various MBTs and various vehicles of the French Army and abroad. The Galix Defensive aids suite has been specially designed to protect the vehicles of the armed forces and internal security forces in times of war or crisis. GALIX offers an optimized response to all known threats, thereby significantly increasing the survivability of armoured vehicles (Regis M, 2007).

The GALIX system provides protection for a combat vehicle in the following situations:

- when identified by the enemy, by avoiding the engagement (IR-visible wideband smoke screen round),
- when engaged by an R-guided missile, by avoiding being hit (IR decoy round),
- when approached by enemy troops, by avoiding the assault (self-protection round),
- when engaging in night time combat, by keeping the main weapon available (illuminating round).

The GALIX system provides riot control vehicles with non-toxic or wounding ammunition (warning or tear gas). Practice ammunition (smoke screen, self-protection) are also proposed. The modularity of the GALIX system enables the type of ammunition, the number of launcher tubes and their positions to be determined according to vehicle mission and capabilities. An example of launcher tube on foreign MET vehicle is given on Figure 2.

Figure 2, Launcher tubes on left turret

The GALIX system consists of launcher tubes accommodating all types of ammunition, a control unit (available in many versions depending on the number of launcher tubes and the integration of a threat detector), various rounds and test equipment.

The ammunition is secured to the launcher tube by a bayonet system. A central pin and the bayonet system provide the electric ignition contact on launcher. This device provides for safe and immediate reloading of ammunition.

Figure 3, ammunition, control unit and test equipment

Launch tubes can be fitted to the vehicle's turret or chassis according to the mission. They can be loaded with any type of GALIX ammunitions (Figure 3):

Wartime ammunition

- GALIX 4 self-protection round.
- GALIX 6 IR decoy round
- GALIX 13 IR-visible wideband smoke screen round.
- GALIX 29 stun warning round

Riot control ammunition

- GALIX 15 irritant round
- GALIX 19 warning round.
- GALIX 29 sturn warning round
- GALIX 46 peacekeeping round

Practice ammunition

- GALIX 17 practice round (smoke screen round).
- GALIX 18 practice round (self-protection round)

Test means

- GALIX 16P tester

5 Inventory analysis

5.1 Galix 13 F1A description

The architecture of the GALIX 13 F1A ammunition is presented on Figure 4 (Regis M, 2007)

It is composed by:

- a case containing:
    - one screening charge. The screening material is pressed then placed in a case with a central tube containing the dispersion charge. It is initiated by a delay
    - two smoke charges. It consists of two pellets with a central tube integrating the firing composition. They are initiated during the fire by the ejection system
- an ejection system containing an ignitor and a propellant charge. This propellant charge will push the three charges outside of the case and initiate the firing composition of the smoke charge and the screening charge delay.

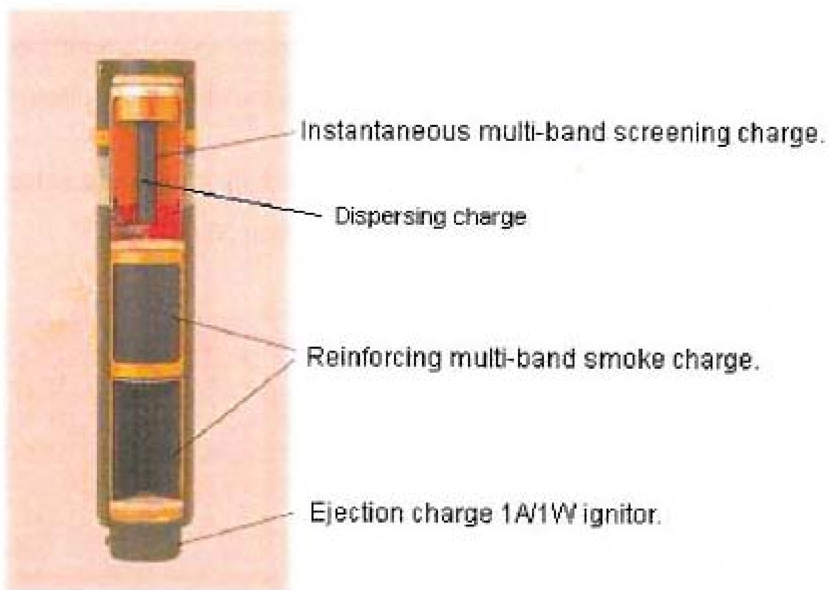


Figure 4, GALIX 13 ammunition

The characteristics of the ammunition are the following:

- calibre (external case): 85 mm
- length : 330 mm
- weight : 4,5 kg

5.1.1 Screen Generation

The GALIX 13 smoke round can provide a smoke screen that includes visual and multiband screening agents over an arc to the front of the vehicle integration that can last up to 30 seconds. This screen can blind any optically or infrared controlled weapon system in less than 2 second.

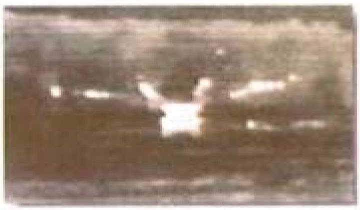
The ammunition is fired from 1 to 8 launch tubes depending of effect and wanted covering sector. For the GALIX 13 F1A ammunition, a usual sector is from 90" (6 launch tubes) to 120" (8 launch tubes) in front of the vehicle integration.

The screening takes effect in less than 2 seconds. Its duration in the visible and infrared is more than 30 seconds.

The vehicle screening is done by creating an opaque screen in the visible and infrared spectra in less than 0,7s, the following figures show the creation of the screen:

- effect of the instantaneous charge and beginning of the burn of the smoke charge (TO + 0,7s)
- deployment of the smoke charge and screening more than 20s

Below is a sequence of pictures showing the screening effect.



T0

T0 + 0,7 s

T0 + 1 s

T0 + 20 s

5.2 Munitions life cycle

5.2.1 Manufacturing

This is the most detailed part of the whole life cycle. The manufacturing process was established with the help of munitions designers from both Nexter and Lacroix. Both companies produced Function material cards for each part in their manufacturing process. That was sixteen cards from Nexter and eight cards from Lacroix.

5.2.2 Storage

The main part of an ordinary munitions life is in storage. The storage can last from everything between 10 to over 30 years but is usually in the latter time frame. However, this is changing due to the change of the “work” of the National armed forces. The storage facilities have climate and humidity controls which mainly use energy in the form of electricity.

In this study the storage phase has been excluded since the study is comparing two different designs which have similar storage phases, and the design of the munitions will not greatly change the storage data.

5.2.3 Use of the munitions

When used, the munitions will spread a smoke screen around a vehicle. Firing the munitions means that all materials in the grenade are combusted and/or spread into the environment. Propellant and explosives in the grenade are combusted and gases are produced. Data for the produced gases has been obtained by the producers and noted in their function material cards.

5.2.4 Demilitarization

The end of life of munitions not used, is in military terms called demilitarisation. The demilitarisations processes are different for different munitions and different countries. In this study the French demilitarisation process for this type of munitions has been used. This demilitarisation process is downsizing military training, which means that the munitions are used in training.

5.3 Format and data categories

SimaPro 7.0 was used and the format and data categories that are therein.

5.4 Data quality

The quality of the data varies and is dependent on the source of data. The quality of the references used will be discussed here:

– Nexter & Lacroix (2009) – This is data from the producer of the munitions which is used in all stages of the manufacturing processes. It also includes emission data for their pure substances which functions by combustion such as pyrotechnics, delayers etc.

– Wilcox et al. (1996) – This reference is a report from the US army. It includes tests on open burning/ open detonation of munitions materials. This is used for explosives or propellants that are burnt or detonated where data are lacking from the above mentioned source. Though the validity is unknown, these are the best available data.

– In addition, data with varying quality have been achieved from the Simapro data bases.

6 Green Galix

After the initial year of the study, the first set of critical items for the Galix 13 F1A was established. This commenced the part where the manufacturing parties should change the design to reduce the environmental impact. The new design called Green Galix resulted and was presented in the end of year two.

Both Nexter and Lacroix have made improvements in the design of Galix 13 by simplifying its design and decreasing the amount of metals, where the largest reduction was in the amount of brass by 14% (without any reduction of the performance). Some metal parts have also been changed to recycled metals.

The largest change of the process was the reuse of parts and manufacturing the munitions so that it could be taken apart. In effect this makes it possible with only small adjustment to increase the lifetime of the munitions at least from 8 years to 16 years. So, instead of manufacturing two munitions items, only one needs to be produced with small complementing parts. This also makes it easier to recycle parts of the munitions when it is no longer possible to prolong the life time.

7 The Database

This chapter describes how the data base is built, and what is presently included and not included.

7.1 Database build-up

The database is based on the information received from Nexter and Lacroix. In Figure 5 the different manufacturing step of the Galix 13 F1A is shown, based on the information received from Nexter and Lacroix. As can be seen the manufacturing starts at Nexter where most of the Galix 13 is done. The whole munitions are then transported to Lacroix where the last part (the Pot brass) is inserted making the Galix is then prepared for delivery to the customer.

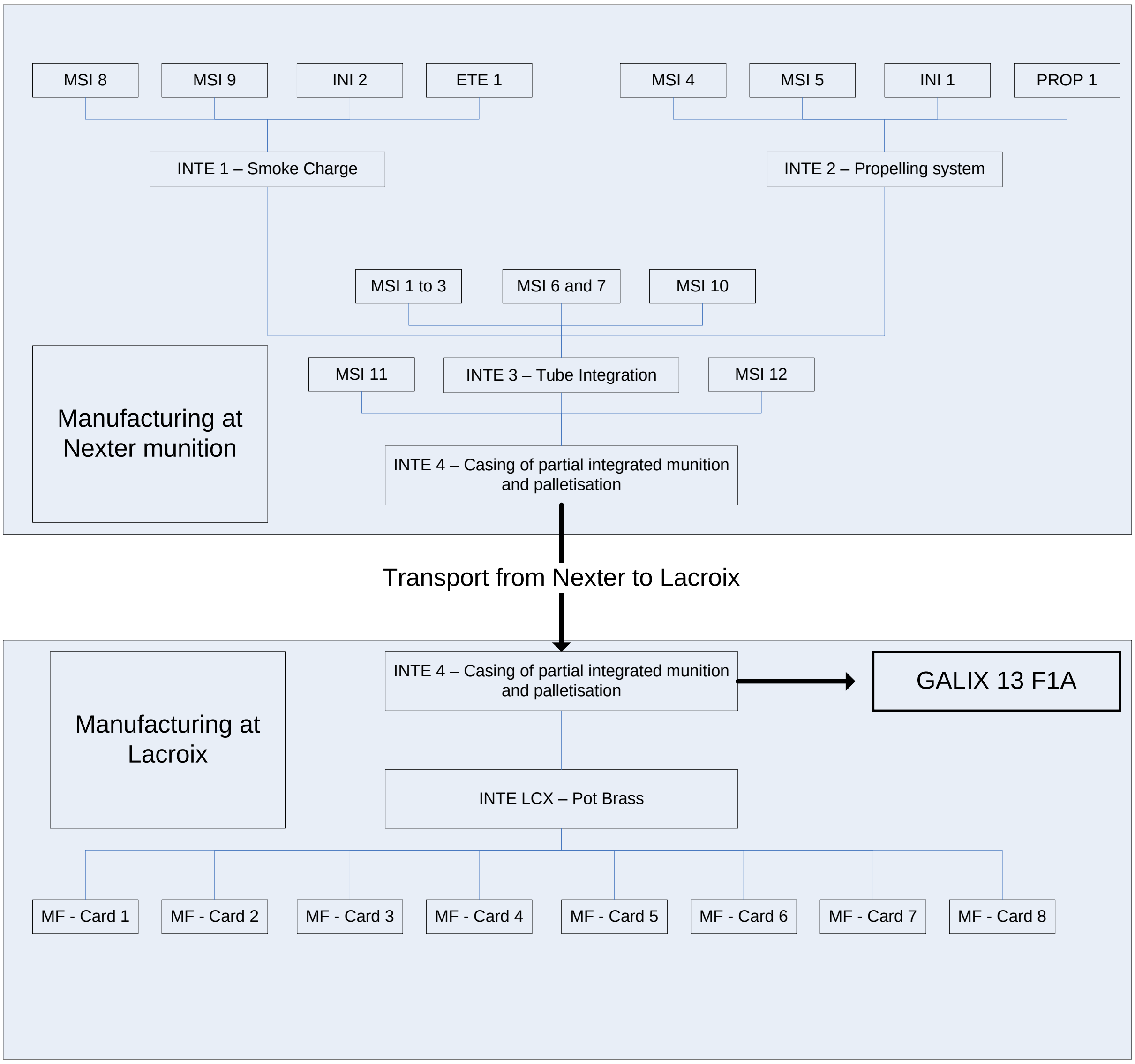


Figure 5, the manufacturing of Galix 13 F1A

The database in Simapro (the software used) is built with the acronyms used by respective companies. One change that has been done is that the integration processes (INTE 1-4) is included in the MSI because of simplicity in the database.

For each card (MSI, INTE, INI, PROP and MF) a corresponding file has been received from Nexter and Lacroix. These contain information about each card such as which material and processes are used or whether it is a black box (se below). This information is then used to build the database.

7.2 Black Boxes

Due to commercial secrets there was a need to hide certain details in some of the companies function material cards. FOI and each company had the full detailed information of these cards which were in the project called “black boxes”. The complete information is included in the full database, but the full data base was only distributed to the companies and the master copy remains at FOI. In all other “open” databases the information from the black boxes is removed.

7.3 Included materials/processes

Table 1 and

Table 2 show the materials and processes that have been manufactured by either FOI, Nexter or Lacroix to be able to process the LCA.

Table 1, Function material cards from Nexter

Card		Note
MSI 1	Cartridge with Connected Ring	
MSI 2	Wedging Felt	
MSI 3	Connected Ring Felt	
MSI 4	Propelling Block	
MSI 5	Ignition Support	
MSI 6	Top	
MSI 7	Piston	
MSI 8	Smoke Charge Casing	
MSI 9	Smoke charge Casing Top	
MSI 10	Propping Ring	
MSI 11	Case	
MSI 12	Pallet	
INI 1	Ignitor	Black Box
INI 2	Ignition Composition	Black Box
PROP 1	Propelling Composition	Black Box
ETE 1	Smoke Composition	Black Box

Table 2, Function material cards from Lacroix

CARD		NOTE
MF 1	Wrap Pot Instantaneous Brass	
MF 2	Cane Bursting	
MF 3	Flask Instantaneous Pot	
MF 4	Half Cockles	
MF 5	Parachute	
MF 6	Initiation Pyrotechnical delay	Black Box
MF 7	Charge of Dispersion	
MF 8	Powder opacifying	

In addition FOI has supplied 9 materials as can be seen in Table 3. These materials are either calculated or collected in other ways.

Table 3, Materials in database from FOI and Lacroix

Materials with calculated data or collected data
Barium chromate
Barium nitrate
Ethanol
Glycerine
Nitro cellulose
Nitro glycerine
Materials with no data
Barium chloride
Centralite I
Potassium chromate

8 Impact assessment

In the Life Cycle Impact Assessment (LCIA) are the results from the inventory analysis further processed and interpreted in terms of environmental impacts and societal preferences (Guinée et al., 2002).

The impact assessment in our study includes a classification, characterisation and two different weighting methods, Ecoindicator-99 and EPS 2000. Each method is briefly described below. The selected impact categories and performance of characterisation are included in the description of the methods. Normalisation and grouping has not been included in our study.

Table 4, Used environmental abbreviations

DALY	**Disability Adjusted Life Years,**
ELU	Environmental Load Units
m2yr	square meter per year
PAF	Potentially Affected Fraction
PDF	Potentially Disappeared Fraction of species.
Pt	Points

8.1 Characterisation methods

The characterisation methods used in this study are baseline methods (Guinée et al., 2002) as included in the SimaPro 7.0 program.

8.2 Weighting methods

8.2.1 Ecoindicator-99

Ecoindicator is developed by PRé consultants in the Netherlands. The methodology is described in Goedkoop and Spriensma (2000). Three different versions of the method are developed, these are:

- The egalitarian perspective: A long term perspective is used. Even a minimum of scientific proof justifies inclusion.
- The hierarchist perspective: A balanced time perspective is used. Effects to be included are determined by consensus among scientists.
- The individualist perspective: A short time perspective is used and only proven effects are included.

In this LCA we have used the hierarchic perspective. In this perspective are substances included if there is consensus among scientists regarding the effect. For example, all carcinogenic substances in IARC (International Agency for Research on Cancer) class 1, 2a and 2b are included, while class 3 has deliberately been excluded. In the hierarchic perspective, damages are assumed to be avoidable by good management. For instance, the danger people who flees from rising water levels experience is not included. In the case of fossil fuels the assumption is made that fossil fuels cannot easily be substituted. Oil and gas are to be replaced by shale, while coal is replaced by brown coal. Weighting is performed for the three damage categories; Human health, Ecosystem quality and Resources. The impact categories and weighting factors are shown in Table 5 below.

Table 5, Impact categories and weighting factors used in Ecoindicator 99 (SimaPro)

Impact category	Weighting factor	Unit
Human health Cancirogen	300	DALY
Human health Resp. org.	300	DALY
Human health Resp. inorg.	300	DALY
Human health Clim.change	300	DALY
Human health Radiation	300	DALY
Human health Ozone Layer	300	DALY
Ecosystem Quality Ecotox	400	PDF*m2yr
Ecosystem Quality Acid/Eutrophication	400	PDF*m2yr
Ecosystem Quality Land use	400	PDF*m2yr
Resources Minerals	300	MJ surplus energy
Resources Fossil fuels	300	MJ surplus energy

For more information, see Goedkoop and Spriensma (2000), information in the SimaPro program and www.pre.nl.

8.2.2 EPS 2000 (Environmental Priority Strategies)

The EPS method is developed within Centre for the environmental assessment of Products and Material systems (CPM) in Sweden. The methodology is described in Steen (1999). Weighting is made through valuation on the five damage categories human health, ecosystem production capacity, abiotic stock resource, biodiversity and also cultural and recreational values. Each damage category consists of impact categories. Weighting factors should represent the willingness to pay to avoid changes, and is calculated as environmental load units (ELU). More information can be found in Steen (1999).

9 Analysis of Galix 13

This is the LCA analysis of the complete original design of the munitions. As seen below we have here established the four critical functions in each company's parts of the munitions.

9.1 Results from EcoIndicator 99

What can be seen in Figure 6 and also in tables 6-8 is that for the Life Cycle of Galix 13 has two the dominant environmental effects. The first (yellow and red staple in Figure 6) is from the use of metals during production. The second one (green staple in Figure 6) originates from spreading all the constituents into the environment during the end of life and thus damaging the environment. This is mostly because of metals spread and damaging the Ecosystem quality.

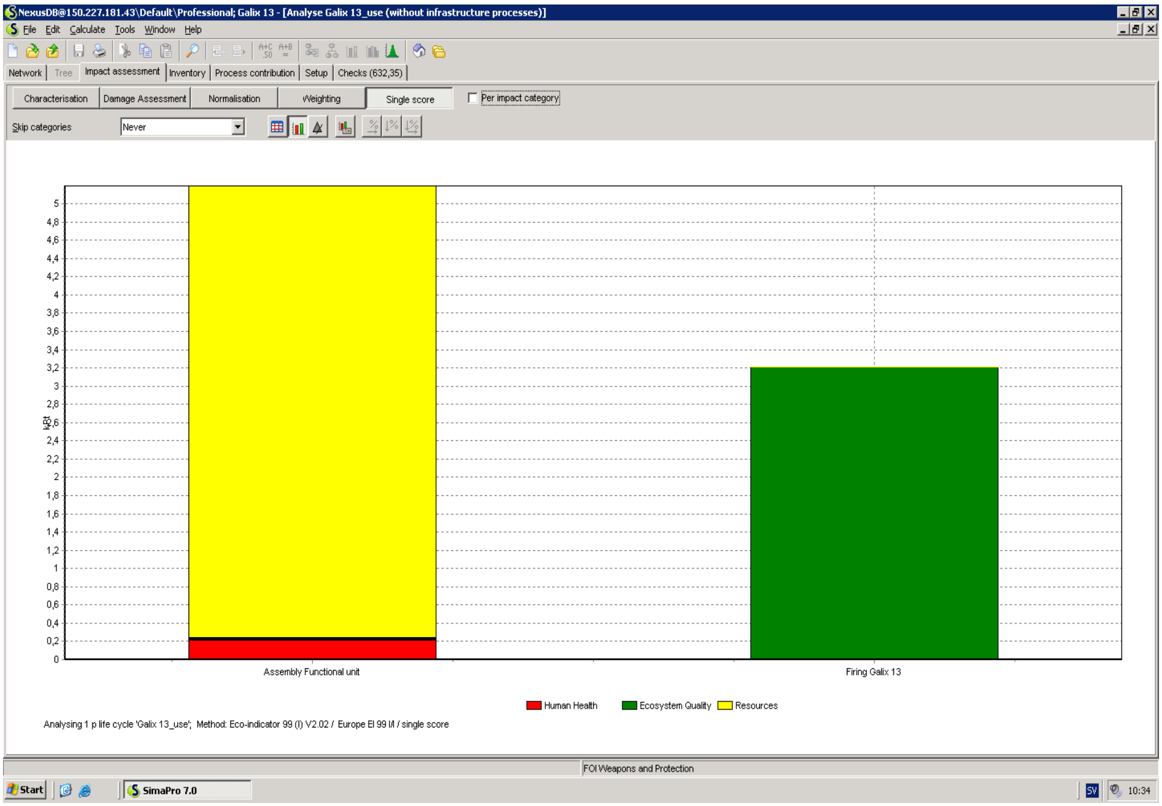


Figure 6, Eco-indicator 99: Single score.

Figure 6, shows the total impact of the munitions as a single score. The score is divided into three categories Human health, Ecosystem quality and Resources. Figure 6 shows the results in two parts, the assembly of the munitions and the firing of the munitions.

Table 6-8, show different presentations of the same simulation as Figure 6, but in different modes. Table 6 and 7 shows only all environmental effects added up into impact categories. Table 8 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 6, Eco-indicator 99: Characterisation

Impact category	Unit	Total	Assembly Functional unit	Firing Galix 13
Carcinogens	DALY	0,000257	0,000257	8,29E-12
Resp. organics	DALY	8,02E-06	2,85E-06	5,17E-06
Resp. inorganics	DALY	0,00238	0,00238	6,74E-07
Climate change	DALY	0,000553	0,000552	9,25E-07
Radiation	DALY	3,39E-07	3,39E-07	0
Ozone layer	DALY	1,94E-07	1,94E-07	0
Ecotoxicity	PAF*m2yr	581000	1850	579000
Acidification/ Eutrophication	PDF*m2yr	69,5	69,4	0,0197
Land use	PDF*m2yr	106	106	0
Minerals	MJ surplus	3710	3710	0

Table 7, Eco-indicator 99: Damage assessment.

Impact category	Unit	Total	Assembly Functional unit	Firing Galix 13
Carcinogens	DALY	0,000257	0,000257	8,29E-12
Resp. organics	DALY	8,02E-06	2,85E-06	5,17E-06
Resp. inorganics	DALY	0,00238	0,00238	6,74E-07
Climate change	DALY	0,000553	0,000552	9,25E-07
Radiation	DALY	3,39E-07	3,39E-07	0
Ozone layer	DALY	1,94E-07	1,94E-07	0
Ecotoxicity	PDF*m2yr	58100	185	57900
Acidification/ Eutrophication	PDF*m2yr	69,5	69,4	0,0197
Land use	PDF*m2yr	106	106	0
Minerals	MJ surplus	3710	3710	0

Table 8, Eco-indicator 99: Weighting

Impact category	Unit	Total	Assembly Functional unit	Firing Galix 13
Total	Pt	8410	5190	3210
Carcinogens	Pt	17,1	17,1	5,52E-07
Resp. organics	Pt	0,534	0,19	0,344
Resp. inorganics	Pt	158	158	0,0449
Climate change	Pt	36,8	36,7	0,0615
Radiation	Pt	0,0225	0,0225	0
Ozone layer	Pt	0,0129	0,0129	0
Ecotoxicity	Pt	3220	10,3	3210
Acidification/ Eutrophication	Pt	3,85	3,85	0,00109
Land use	Pt	5,9	5,9	0
Minerals	Pt	4960	4960	0

9.2 Result from EPS 2000

The result from EPS for Galix 13 shows an overwhelming large impact from using resources. This is easily seen in Figure 7 and table 9-11. In table 9-11 the use of resources is shown as depletion as reserves.

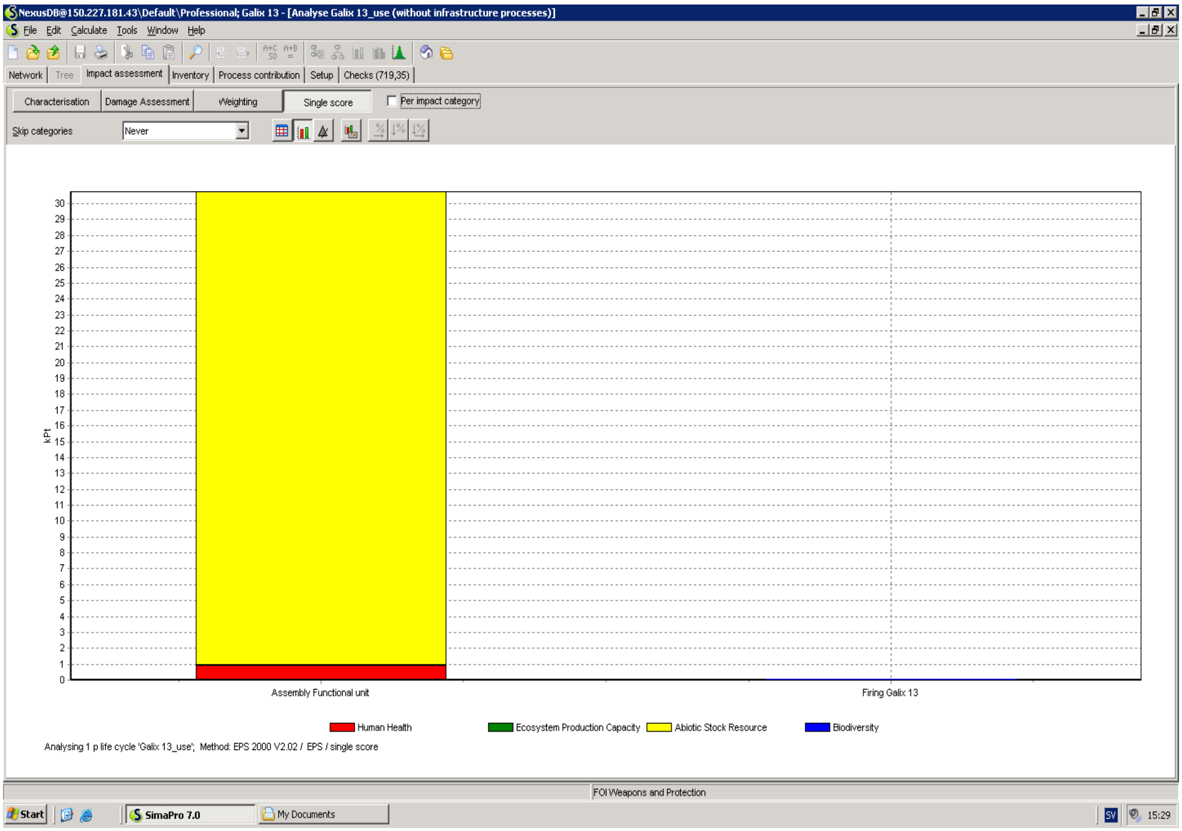


Figure 7, EPS 2000 Single score

Figure 7, shows the total impact of the munitions as a single score. The score is divided into four categories Human health, Ecosystem production Capacity, Ambiotic Stock Resources and biodiversity. Figure 7 shows the results in two parts, the assembly of the munitions and the firing of the munitions.

Table 9-11, show different presentations of the same simulation as Figure 7, but in different mode. Table 9 shows only all environmental effects added up into impact categories. Table 10 shows the results from Table 9 but calculated as ELU. Table 11 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 9, EPS 2000 Characterisation.

Impact category	Unit	Total	Assembly Functional unit	Firing Galix 13
Life Expectancy	PersonYr	0,00762	0,00732	0,000302
Severe Morbidity	PersonYr	0,00133	0,00122	0,00011
Morbidity	PersonYr	0,00205	0,00205	4,78E-06
Severe Nuisance	PersonYr	0,0181	0,0181	0
Nuisance	PersonYr	0,157	0,156	0,000566
Crop Growth Capacity	kg	31,7	8,62	23,1
Wood Growth Capacity	kg	-99,8	-96,2	-3,61
Fish and Meat production	kg	-0,377	-0,377	0,000124
Soil Acidification	H+ eq.	38,4	38,2	0,178
Prod. Cap. Irrigation Water	kg	6,99	6,99	0
Prod. Cap. Drinking water	kg	6,99	6,99	0
Depletion of reserves	ELU	32600	32600	0
Species Extinction	NEX	7,2E-11	6,82E-11	3,8E-12

Table 10, EPS 2000 Damage assessment

Impact category	Unit	Total	Assembly Functional unit	Firing Galix 13
Life Expectancy	ELU	648	622	25,7
Severe Morbidity	ELU	133	122	11
Morbidity	ELU	20,5	20,5	0,0478
Severe Nuisance	ELU	181	181	0
Nuisance	ELU	15,7	15,6	0,0566
Crop Growth Capacity	ELU	4,76	1,29	3,47
Wood Growth Capacity	ELU	-3,99	-3,85	-0,145
Fish and Meat production	ELU	-0,377	-0,377	0,000124
Soil Acidification	ELU	0,384	0,382	0,00178
Prod. Cap. Irrigation Water	ELU	0,021	0,021	0
Prod. Cap. Drinking water	ELU	0,21	0,21	0
Depletion of reserves	ELU	32600	32600	0
Species Extinction	ELU	7,91	7,49	0,422

Table 11, EPS 2000 Weighting

Impact category	Unit	Total	Assembly Functional unit	Firing Galix 13
Total	Pt	33600	33600	40,6
Life Expectancy	Pt	648	622	25,7
Severe Morbidity	Pt	133	122	11
Morbidity	Pt	20,5	20,5	0,0478
Severe Nuisance	Pt	181	181	0
Nuisance	Pt	15,7	15,6	0,0566
Crop Growth Capacity	Pt	4,76	1,29	3,47
Wood Growth Capacity	Pt	-3,99	-3,85	-0,145
Fish and Meat production	Pt	-0,377	-0,377	0,000124
Soil Acidification	Pt	0,384	0,382	0,00178
Prod. Cap. Irrigation Water	Pt	0,021	0,021	0
Prod. Cap. Drinking water	Pt	0,21	0,21	0
Depletion of reserves	Pt	32600	32600	0
Species Extinction	Pt	7,91	7,49	0,422

9.2.1 Critical Items evaluated from calculation

From the LCA-calculation the four most critical items for Nexter and Lacroix has been identified. These can bee seen below in Table 12 for Nexter and Table 13 for Lacroix. This has been established by weighting each process contribution to the whole environmental impact. They are listed in the order of importance; number one has the largest impact, number two the second largest and so on. The most critical card for the whole munitions is Lacroix Card 8, the environmental effect comes from the Brass in this card. In the analyses the critical items from number 2 to 4 are close in environmental impact and their order is actually depending on the person making the evaluation. Actually the table could be read as one card as number 1 and three cards as number 2. The final evaluation is always depending of subjective estimation.

Table 12, Critical Items for Nexter

No	Critical Item	Card
1	Steel	MSI 1
2	E2	FFM 16
3	Steel	MSI 4
4	Smoke charge casing	MSI 8

Table 13, Critical Items for Lacroix

No	Critical Item	Card
1	Brass	FM Card 8
2	AlCuMg (2017)	FM Card 3
3	Aluminium	FM Card 1
4	Zinc steel	FM Card 5

10 Analysis of Green Galix

As mentioned in chapter 6, Both Nexter and Lacroix have made improvements of Galix 13 by simplifying its design and decreasing the amount of metals, where the largest reduction was in the amount of brass by 14% (without any reduction of the performance). Some metal parts have also been changed to recycled metals

Here, the LCA of the new design is described in a similar manner as above. Even here, four critical items have been identified.

10.1 Results from EcoIndicator 99

What can be seen in Figure 8 and also in tables 14-16 is that also the Life Cycle of Green Galix has two dominant environmental effects. The first (yellow and red staple in Figure 8) are from the use of metals during production. The second one (green staple in Figure 8) originates from spreading all the constituents into the environment during the end of life and thus damaging the environment. This is mostly because of metals spread and damaging the Ecosystem quality.

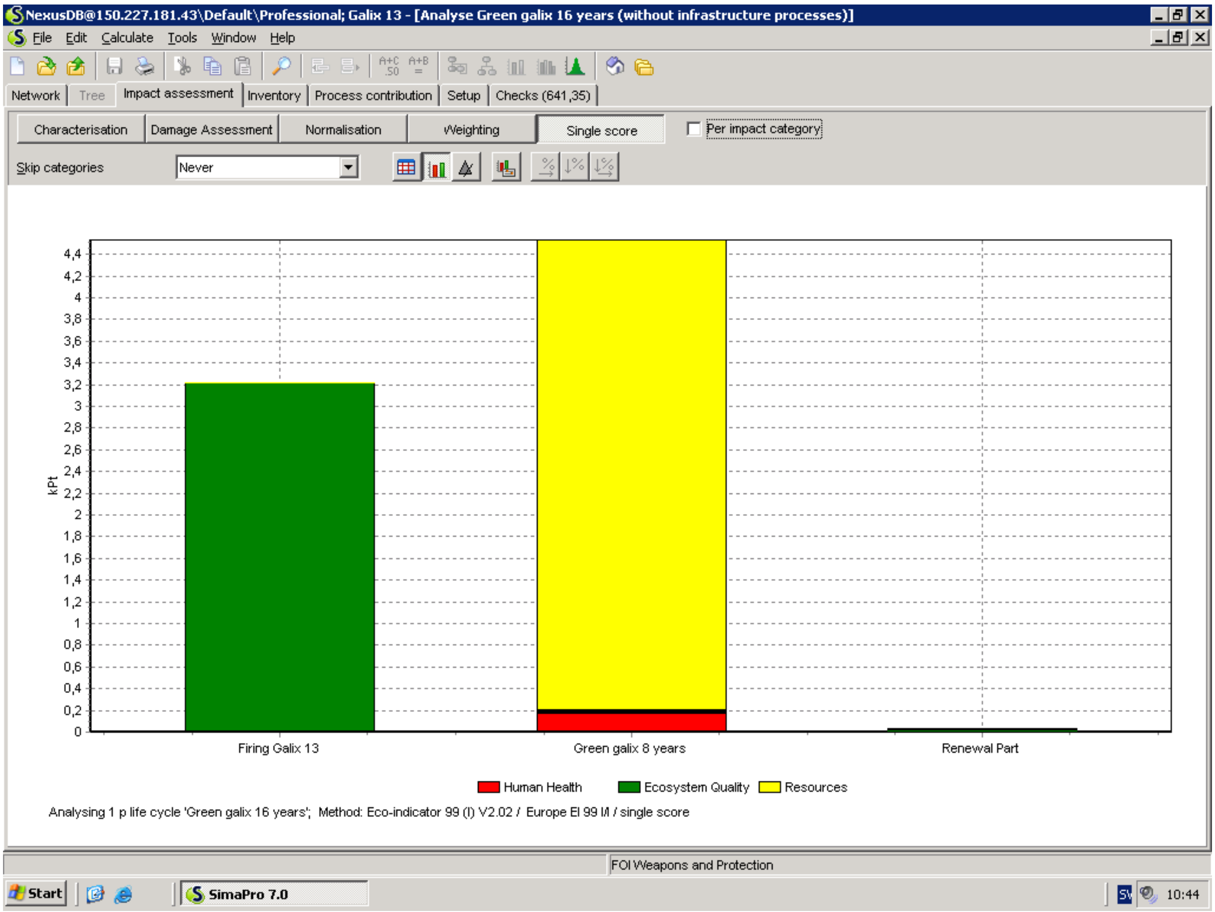


Figure 8, Eco-indicator 99: Single score.

Figure 8, shows the total impact of the munitions as a single score. The score is divided into three categories Human health, Ecosystem quality and resources. Figure 8 shows the results in three parts, the assembly of the munitions, the assembly of the renewal part and the firing of the munitions.

Table 14-16, show different presentations of the same simulation as Figure 8, but in different modes. Table 14 and 15 shows only all environmental effects added up into impact categories. Table 16 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 14, Eco-indicator 99: Characterisation.

Impact category	Unit	Total	Firing Galix	Green Galix 8 years	Renewal Part
Carcinogens	DALY	0,000204	8,29E-12	0,0002	3,96E-06
Resp. organics	DALY	8,36E-06	5,17E-06	2,49E-06	6,94E-07
Resp. inorganics	DALY	0,00188	6,74E-07	0,00182	5,69E-05
Climate change	DALY	0,000499	9,25E-07	0,000451	0,000047
Radiation	DALY	3,06E-07	1,65E-23	2,9E-07	1,61E-08
Ozone layer	DALY	1,16E-06	3,94E-23	1,83E-07	9,79E-07
Ecotoxicity	PAF*m2yr	580000	579000	1560	10,2
Acidification/ Eutrophication	PDF*m2yr	60,6	0,0197	55,6	4,99
Land use	PDF*m2yr	94	5,09E-15	83,9	10,1
Minerals	MJ surplus	2890	1,58E-13	2860	20,7

Table 15, Eco-indicator 99: Damage assessment.

Impact category	Unit	Total	Firing Galix	Green Galix 8 years	Renewal Part
Carcinogens	DALY	0,000204	8,29E-12	0,0002	3,96E-06
Resp. organics	DALY	8,36E-06	5,17E-06	2,49E-06	6,94E-07
Resp. inorganics	DALY	0,00188	6,74E-07	0,00182	5,69E-05
Climate change	DALY	0,000499	9,25E-07	0,000451	0,000047
Radiation	DALY	3,06E-07	1,65E-23	2,9E-07	1,61E-08
Ozone layer	DALY	1,16E-06	3,94E-23	1,83E-07	9,79E-07
Ecotoxicity	PDF*m2yr	58000	57900	156	1,02
Acidification/ Eutrophication	PDF*m2yr	60,6	0,0197	55,6	4,99
Land use	PDF*m2yr	94	5,09E-15	83,9	10,1
Minerals	MJ surplus	2890	1,58E-13	2860	20,7

Table 16, Eco-indicator 99: Weighting

Impact category	Unit	Total	Firing Galix	Green Galix 8 years	Renewal Part
Total	Pt	0,0247	1E-09	0,0242	0,00048
Carcinogens	Pt	0,00101	0,000626	0,000301	0,000084
Resp. organics	Pt	0,227	8,16E-05	0,22	0,00689
Resp. inorganics	Pt	0,0604	0,000112	0,0546	0,00568
Climate change	Pt	0,000037	2E-21	3,51E-05	1,94E-06
Radiation	Pt	0,000141	4,77E-21	2,21E-05	0,000118
Ozone layer	Pt	12,9	12,9	0,0347	0,000227
Ecotoxicity	Pt	0,0135	4,37E-06	0,0124	0,00111
Acidification/ Eutrophication	Pt	0,0209	1,13E-18	0,0186	0,00224
Land use	Pt	19,3	1,06E-15	19,1	0,138
Minerals	Pt	0,0247	1E-09	0,0242	0,00048

10.2 Results from EPS 2000

The result from EPS for Green Galix shows an overwhelming large impact from using resources. This is easily seen in Figure 9 and table 17-19. In table 17-19 the use of resources is shown as depletion as reserves.

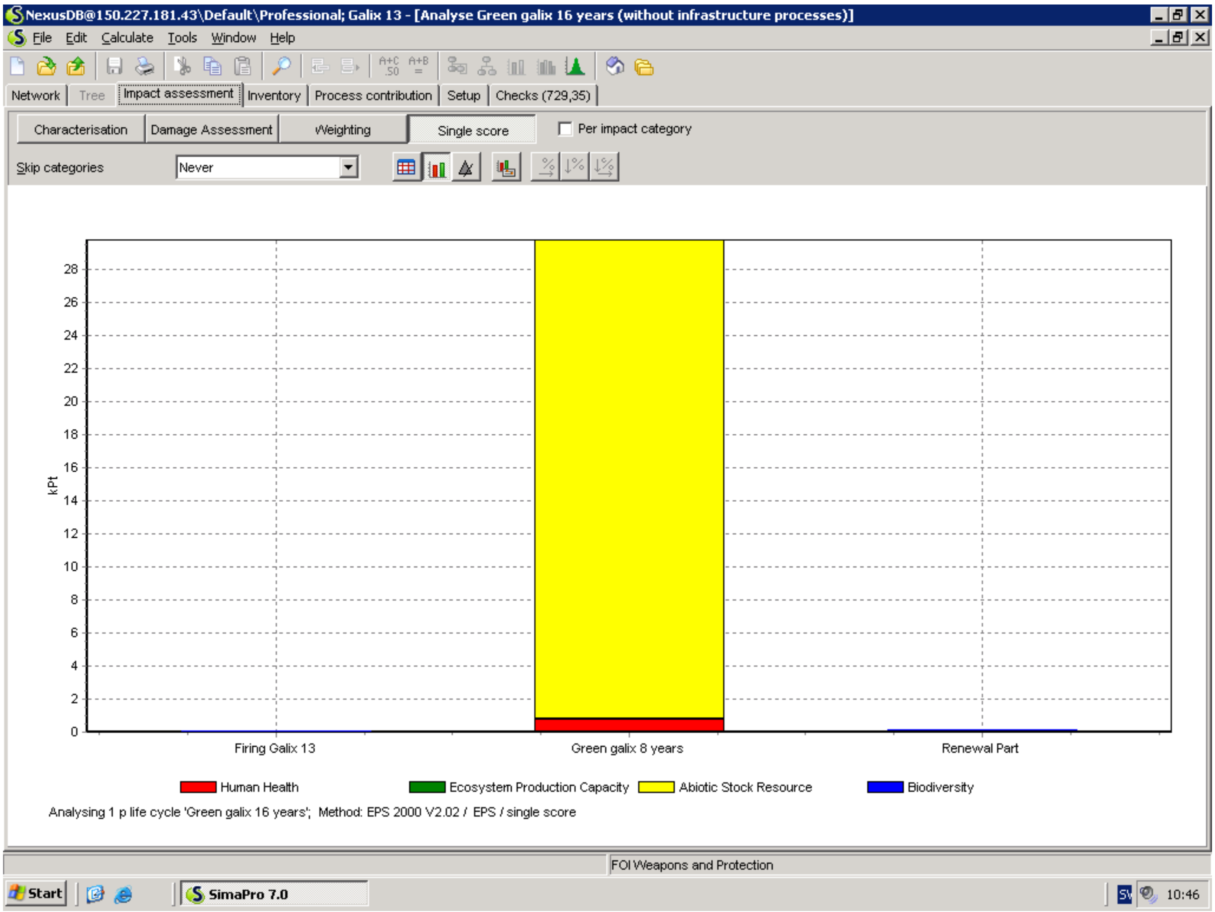


Figure 9, EPS 2000 Single score

Figure 9, shows the total impact of the munitions as a single score. The score is divided into four categories Human health, Ecosystem production Capacity, Ambiotic Stock Resources and biodiversity. Figure 9 shows the results in two parts, the assembly of the munitions and the firing of the munitions.

Table 17-19, show different presentations of the same simulation as Figure 9, but in different mode. Table 17 shows only all environmental effects added up into impact categories. Table 18 shows the results from Table 17 but calculated as ELU. Table 19 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 17, EPS 2000 Characterisation

Impact category	Unit	Total	Firing Galix	Green Galix 8 years	Renewal Part
Life Expectancy	PersonYr	0,00618	0,000302	0,00534	0,000544
Severe Morbidity	PersonYr	0,00114	0,00011	0,000881	0,00015
Morbidity	PersonYr	0,00183	4,78E-06	0,00166	0,000169
Severe Nuisance	PersonYr	0,0156	8,66E-19	0,0156	6,81E-06
Nuisance	PersonYr	0,127	0,000566	0,119	0,00778
Crop Growth Capacity	kg	32,2	23,1	7,27	1,79
Wood Growth Capacity	kg	-88,5	-3,61	-75	-9,94
Fish and Meat production	kg	-0,317	0,000124	-0,292	-0,025
Soil Acidification	H+ eq.	31,6	0,178	29,2	2,15
Prod. Cap. Irrigation Water	kg	8,1	4,22E-16	6,99	1,11
Prod. Cap. Drinking water	kg	8,1	4,22E-16	6,99	1,11
Depletion of reserves	ELU	26300	1,46E-12	26200	56,6
Species Extinction	NEX	6,34E-11	3,83E-12	5,61E-11	3,41E-12

Table 18, EPS 2000 Damage assessment

Impact category	Unit	Total	Firing Galix	Green Galix 8 years	Renewal Part
Life Expectancy	ELU	526	25,7	454	46,2
Severe Morbidity	ELU	114	11	88,1	15
Morbidity	ELU	18,3	0,0478	16,6	1,69
Severe Nuisance	ELU	156	8,66E-15	156	0,0681
Nuisance	ELU	12,7	0,0566	11,9	0,778
Crop Growth Capacity	ELU	4,82	3,47	1,09	0,268
Wood Growth Capacity	ELU	-3,54	-0,145	-3	-0,398
Fish and Meat production	ELU	-0,317	0,000124	-0,292	-0,025
Soil Acidification	ELU	0,316	0,00178	0,292	0,0215
Prod. Cap. Irrigation Water	ELU	0,0243	1,26E-18	0,021	0,00334
Prod. Cap. Drinking water	ELU	0,243	1,26E-17	0,21	0,0334
Depletion of reserves	ELU	26300	1,46E-12	26200	56,6
Species Extinction	ELU	6,97	0,422	6,17	0,375

Table 19, EPS 2000 Weighting

Impact category	Unit	Total	Firing Galix	Green Galix 8 years	Renewal Part
Total	Pt	27100	40,6	27000	121
Life Expectancy	Pt	526	25,7	454	46,2
Severe Morbidity	Pt	114	11	88,1	15
Morbidity	Pt	18,3	0,0478	16,6	1,69
Severe Nuisance	Pt	156	8,66E-15	156	0,0681
Nuisance	Pt	12,7	0,0566	11,9	0,778
Crop Growth Capacity	Pt	4,82	3,47	1,09	0,268
Wood Growth Capacity	Pt	-3,54	-0,145	-3	-0,398
Fish and Meat production	Pt	-0,317	0,000124	-0,292	-0,025
Soil Acidification	Pt	0,316	0,00178	0,292	0,0215
Prod. Cap. Irrigation Water	Pt	0,0243	1,26E-18	0,021	0,00334
Prod. Cap. Drinking water	Pt	0,243	1,26E-17	0,21	0,0334
Depletion of reserves	Pt	26300	1,46E-12	26200	56,6
Species Extinction	Pt	6,97	0,422	6,17	0,375

10.2.1 Critical Items evaluated from calculation

As above we have evaluated each cards part of the entire environmental effect. Compared to the original design we can see only small changes. As before Card 8 from Lacroix is clearly the largest impact from the whole munitions. We also still see Card 1 from Nexter as their largest. As for position 2-4 there still is very small differences between cards. Still we can see that the order of cards changes position.

Table 20, Critical Items for Nexter

No	Critical Item	Card
1	Steel	MSI 1
2	E2	FFM 16
3	Ignition Composition	FFM 14
4	Steel	MSI 4

Table 21, Critical Items for Lacroix

No	Critical Item	Card
1	Brass	FM Card 8
2	Wrap pot Instantaneous Brass	FM Card 1
3	Cane Bursting	FM Card 2
4	Flask instantaneous pot	FM Card 3

11 Comparison Galix 13 F1A and Green Galix under 16 years

The largest impact is not actually the change of materials but changes in the general approach. The new design is made for a longer life and to enable the reuse of parts of the munitions in newer munitions. This is not clear when only looking at each LCA. In the comparative LCA the changes due to the general approach can be seen.

To get a comparison of Galix 13 F1A and Green Galix under 16 years, it is needed to produce two munitions for each munitions of the Green Galix. During these 16 years the Green Galix has to go to the manufacturer for exchange of some materials. The delay part in the brass pot is exchanged and this will elongate the life cycle for Green Galix to 16 years

11.1 Results from EcoIndicator 99

As can be seen here the design changes made from Galix 13 to Green Galix reduces the total environmental impact with more than 50%. This reduction is mostly due to the prolongation of the life cycle for Green Galix. The reduction of brass by 14% has great influence as well as the other improvements in Green Galix. We can in the following tables see that minerals and carcinogens are the two impact categories with the largest reductions.

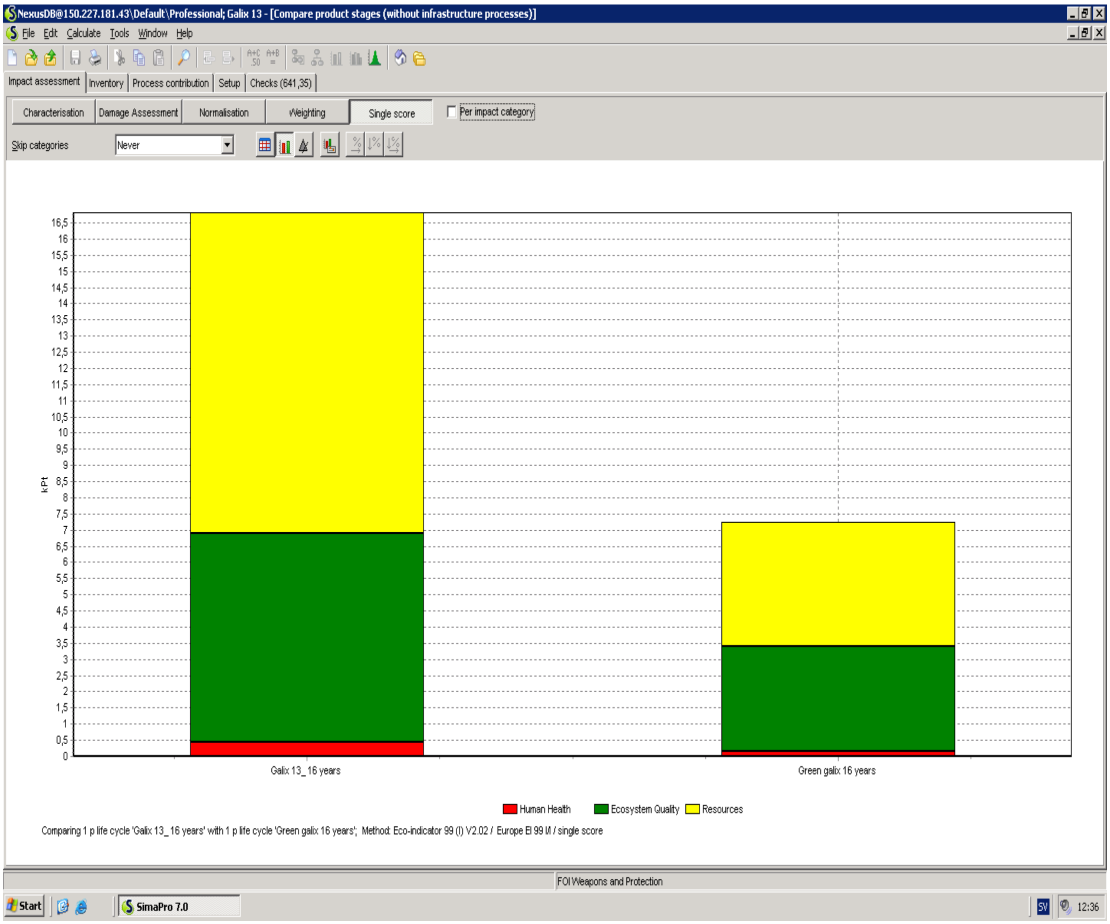


Figure 10, Eco-indicator 99: Single score..

Figure 10, shows the total impact of the munitions as a single score. The score is divided into three categories Human health, Ecosystem quality and resources. Figure 10 shows the results as a comparison between Galix 13 and Green Galix.

Table 22-24, show different presentations of the same simulation as Figure 10, but in different modes. Table 22 and 23 shows only all environmental effects added up into impact categories. Table 24 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 22, Eco-indicator 99: Characterisation

Impact category	**Unit**	**Galix 13**	**Green Galix**	**Impact from Green Galix as % of Galix 13 impact**
Carcinogens	DALY	0,000514	0,000204	39,7
Resp. organics	DALY	0,000016	8,36E-06	52,3
Resp. inorganics	DALY	0,00476	0,00188	39,5
Climate change	DALY	0,00111	0,000499	45,0
Radiation	DALY	6,78E-07	3,06E-07	45,1
Ozone layer	DALY	3,87E-07	1,16E-06	299,7
Ecotoxicity	PAF*m2yr	1160000	580000	50,0
Acidification/ Eutrophication	PDF*m2yr	139	60,6	43,6
Land use	PDF*m2yr	213	94	44,1
Minerals	MJ surplus	7430	2890	38,9

Table 23, Eco-indicator 99: Damage assessment

Impact category	**Unit**	**Galix 13**	**Green Galix**	**Impact from Green Galix as % of Galix 13 impact**
Carcinogens	DALY	0,000514	0,000204	39,7
Resp. organics	DALY	0,000016	8,36E-06	52,3
Resp. inorganics	DALY	0,00476	0,00188	39,5
Climate change	DALY	0,00111	0,000499	45,0
Radiation	DALY	6,78E-07	3,06E-07	45,1
Ozone layer	DALY	3,87E-07	1,16E-06	299,7
Ecotoxicity	PDF*m2yr	116000	58000	50,0
Acidification/ Eutrophication	PDF*m2yr	139	60,6	43,6
Land use	PDF*m2yr	213	94	44,1
Minerals	MJ surplus	7430	2890	38,9

Table 24, Eco-indicator 99: Weighting

Impact category	**Unit**	**Galix 13**	**Green Galix**	**Impact from Green Galix as % of Galix 13 impact**
Total	Pt	16800	7260	43,2
Carcinogens	Pt	34,2	13,6	39,8
Resp. organics	Pt	1,07	0,556	52,0
Resp. inorganics	Pt	317	125	39,4
Climate change	Pt	73,6	33,2	45,1
Radiation	Pt	0,0451	0,0204	45,2
Ozone layer	Pt	0,0258	0,0773	299,6
Ecotoxicity	Pt	6450	3220	49,9
Acidification/ Eutrophication	Pt	7,71	3,37	43,7
Land use	Pt	11,8	5,22	44,2
Minerals	Pt	9930	3850	38,8

11.2 Results from EPS 2000

The results from EPS show an environmental impact reduction of about 60%. It mostly comes from reductions in the impact categories depletion of reserves, Life Expectancy and Nuisance.

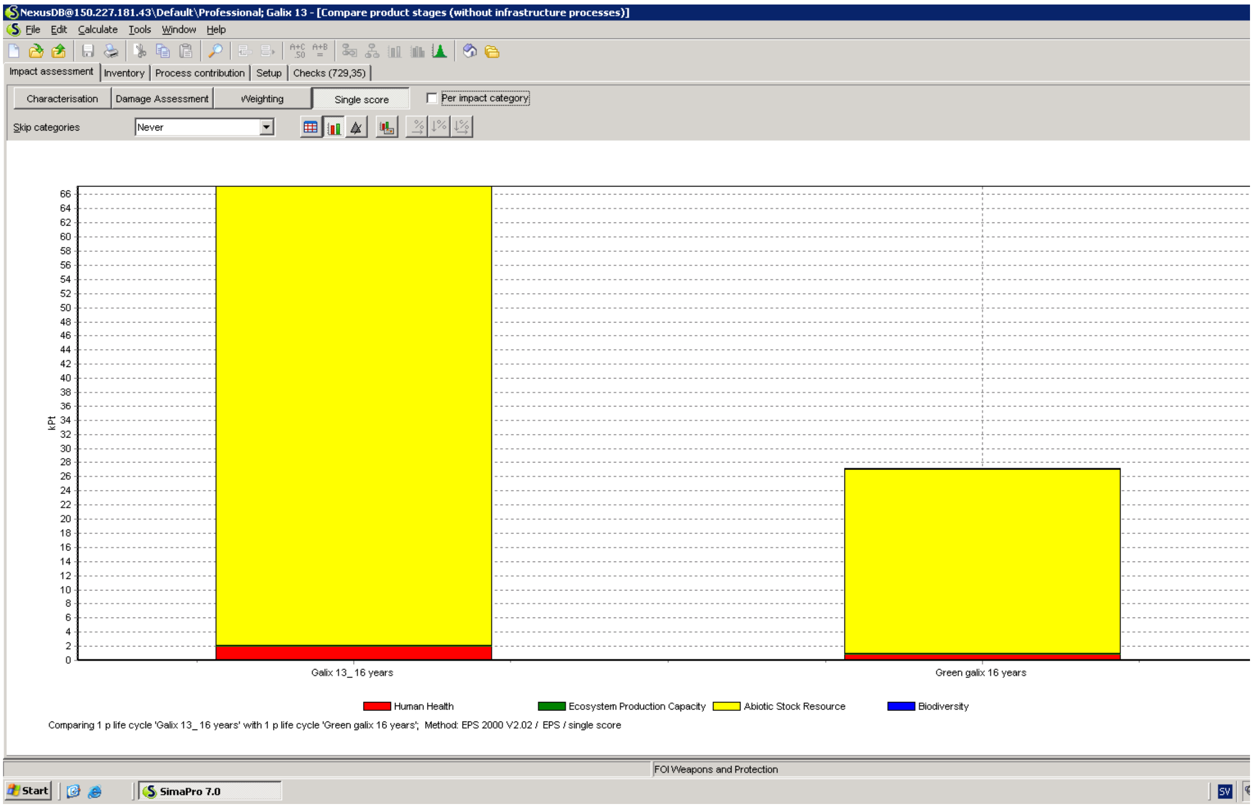


Figure 11, EPS 2000 Single score.

Figure 11, shows the total impact of the munitions as a single score. The score is divided into four categories Human health, Ecosystem production Capacity, Ambiotic Stock Resources and biodiversity. Figure 11 shows the results as a comparison between Galix 13 and Green Galix.

Table 25-27, show different presentations of the same simulation as Figure 11, but in different mode. Table 25 shows only all environmental effects added up into impact categories. Table 26 shows the results from Table 17 but calculated as ELU. Table 27 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 25, EPS 200 Characterisation

Impact category	**Unit**	**Galix 13**	**Green Galix**	**Impact from Green Galix as % of Galix 13 impact**
Life Expectancy	PersonYr	0,0152	0,00618	40,7
Severe Morbidity	PersonYr	0,00265	0,00114	43,0
Morbidity	PersonYr	0,00411	0,00183	44,5
Severe Nuisance	PersonYr	0,0361	0,0156	43,2
Nuisance	PersonYr	0,314	0,127	40,4
Crop Growth Capacity	kg	63,5	32,2	50,7
Wood Growth Capacity	kg	-200	-88,5	44,3
Fish and Meat production	kg	-0,753	-0,317	42,1
Soil Acidification	H+ eq.	76,8	31,6	41,1
Prod. Cap. Irrigation Water	kg	14	8,1	57,9
Prod. Cap. Drinking water	kg	14	8,1	57,9
Depletion of reserves	ELU	65200	26300	40,3
Species Extinction	NEX	1,44E-10	6,34E-11	44,0

Table 26, EPS 2000 Damage Assessment

Impact category	**Unit**	**Galix 13**	**Green Galix**	**Impact from Green Galix as % of Galix 13 impact**
Life Expectancy	ELU	1300	526	40,5
Severe Morbidity	ELU	265	114	43,0
Morbidity	ELU	41,1	18,3	44,5
Severe Nuisance	ELU	361	156	43,2
Nuisance	ELU	31,4	12,7	40,4
Crop Growth Capacity	ELU	9,52	4,82	50,6
Wood Growth Capacity	ELU	-7,98	-3,54	44,4
Fish and Meat production	ELU	-0,753	-0,317	42,1
Soil Acidification	ELU	0,768	0,316	41,1
Prod. Cap. Irrigation Water	ELU	0,0419	0,0243	58,0
Prod. Cap. Drinking water	ELU	0,419	0,243	58,0
Depletion of reserves	ELU	65200	26300	40,3
Species Extinction	ELU	15,8	6,97	44,1

Table 27, EPS 200 Weighting

Impact category	Unit	Galix 13	Green Galix	Impact from Green Galix as % of Galix 13 impact
Total	Pt	67200	27100	40,3
Life Expectancy	Pt	1300	526	40,5
Severe Morbidity	Pt	265	114	43,0
Morbidity	Pt	41,1	18,3	44,5
Severe Nuisance	Pt	361	156	43,2
Nuisance	Pt	31,4	12,7	40,4
Crop Growth Capacity	Pt	9,52	4,82	50,6
Wood Growth Capacity	Pt	-7,98	-3,54	44,4
Fish and Meat production	Pt	-0,753	-0,317	42,1
Soil Acidification	Pt	0,768	0,316	41,1
Prod. Cap. Irrigation Water	Pt	0,0419	0,0243	58,0
Prod. Cap. Drinking water	Pt	0,419	0,243	58,0
Depletion of reserves	Pt	65200	26300	40,3
Species Extinction	Pt	15,8	6,97	44,1

12 Comparison of Galix 13 F1A and Green Galix under 8 years

The largest difference in the above comparison is due to the ability to increase the life time from 8 to 16 years with only a smaller modification of the munitions after 8 years.

By comparing Galix 13 and Green Galix for only 8 years the improvements due solely to material changes can be seen. The reduction of brass, more use of recycled metals and simplified modification of some details made a positive effect. Altogether it is an improvement by more than 10% in total.

12.1 Results from EcoIndicator 99

As can be expected the reduction when not taking into consideration the effects for prolong life time are much smaller. Instead of 60% reduction in this case it is only about 10%. This reduction comes mainly from use of fewer resources. Also here the largest reduction is in the impact categories minerals and carcinogens.

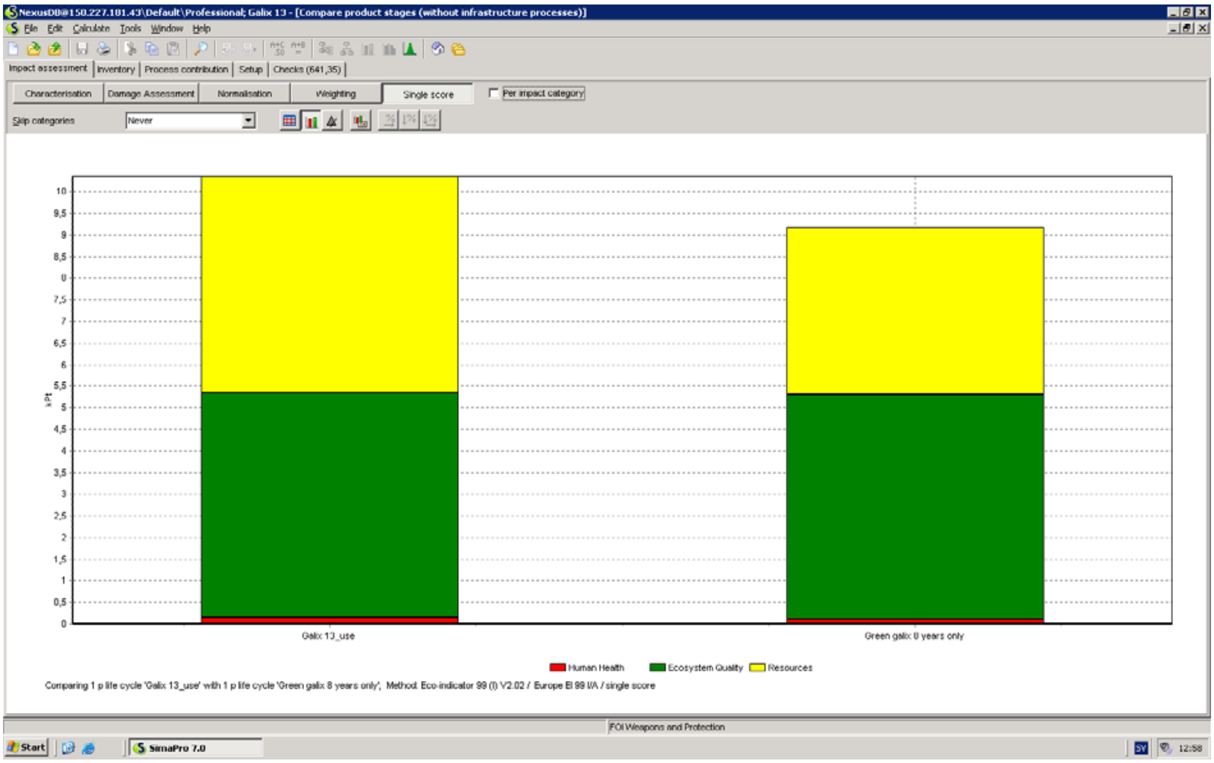


Figure 12, Eco-Indicator 99: Single Score.

Figure 12, shows the total impact of the munitions as a single score. The score is divided into three categories Human health, Ecosystem quality and resources. Figure 12 shows the results as a comparison between Galix 13 and Green Galix.

Table 28-30, show different presentations of the same simulation as Figure 12, but in different modes. Table 28 and 29 shows only all environmental effects added up into impact categories. Table 30 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 28, Eco-Indicator 99: Characterisation

Impact category	Unit	Galix 13	Green Galix	Impact from Green Galix as % of Galix 13 impact
Carcinogens	DALY	0,000257	0,0002	77,8
Resp. organics	DALY	8,02E-06	7,66E-06	95,5
Resp. inorganics	DALY	0,00238	0,00182	76,5
Climate change	DALY	0,000553	0,000452	81,7
Radiation	DALY	3,39E-07	2,9E-07	85,5
Ozone layer	DALY	1,94E-07	1,83E-07	94,3
Ecotoxicity	PAF*m2yr	581000	580000	99,8
Acidification/ Eutrophication	PDF*m2yr	69,5	55,7	80,1
Land use	PDF*m2yr	106	83,9	79,2
Minerals	MJ surplus	3710	2860	77,1

Table 29, Eco-indicator 99: Damage assessment

Impact category	Unit	Galix 13	Green Galix	Impact from Green Galix as % of Galix 13 impact
Carcinogens	DALY	0,000257	0,0002	77,8
Resp. organics	DALY	8,02E-06	7,66E-06	95,5
Resp. inorganics	DALY	0,00238	0,00182	76,5
Climate change	DALY	0,000553	0,000452	81,7
Radiation	DALY	3,39E-07	2,9E-07	85,5
Ozone layer	DALY	1,94E-07	1,83E-07	94,3
Ecotoxicity	PDF*m2yr	58100	58000	99,8
Acidification/ Eutrophication	PDF*m2yr	69,5	55,7	80,1
Land use	PDF*m2yr	106	83,9	79,2
Minerals	MJ surplus	3710	2860	77,1

Table 30, Eco-indicator 99: Weighting

Impact category	Unit	Galix 13	Green Galix	Impact from Green Galix as % of Galix 13 impact
Total	Pt	10400	9160	88,1
Carcinogens	Pt	12,4	9,67	78,0
Resp. organics	Pt	0,388	0,371	95,6
Resp. inorganics	Pt	115	88,1	76,6
Climate change	Pt	26,7	21,9	82,0
Radiation	Pt	0,0164	0,014	85,4
Ozone layer	Pt	0,00938	0,00884	94,2
Ecotoxicity	Pt	5160	5150	99,8
Acidification/ Eutrophication	Pt	6,17	4,94	80,1
Land use	Pt	9,45	7,45	78,8
Minerals	Pt	5030	3880	77,1

12.2 Results from EPS 2000

Also in EPS a smaller reduction can be seen in this simulation. Here the reduction is about 20% instead of 60%. We see the largest reduction in impact categories Severe Morbidity and Life Expectancy.

Figure 13, EPS 2000 Single score.

Figure 13, shows the total impact of the munitions as a single score. The score is divided into four categories Human health, Ecosystem production Capacity, Ambiotic Stock Resources and biodiversity. Figure 13 shows the results as a comparison between Galix 13 and Green Galix.

Table 31-33, show different presentations of the same simulation as Figure 13, but in different mode. Table 31 shows only all environmental effects added up into impact categories. Table 32 shows the results from Table 31 but calculated as ELU. Table 33 shows the same impact categories but here the environmental effect is weighted according to the method.

Table 31, EPS 2000: Characterisation

Impact category	Unit	Galix 13	Green Galix	Impact from Green Galix as % of Galix 13 impact
Life Expectancy	PersonYr	0,00762	0,00564	74,0
Severe Morbidity	PersonYr	0,00133	0,000992	74,6
Morbidity	PersonYr	0,00205	0,00166	81,0
Severe Nuisance	PersonYr	0,0181	0,0156	86,2
Nuisance	PersonYr	0,157	0,119	75,8
Crop Growth Capacity	kg	31,7	30,4	95,9
Wood Growth Capacity	kg	-99,8	-78,6	78,8
Fish and Meat production	kg	-0,377	-0,292	77,5
Soil Acidification	H+ eq.	38,4	29,4	76,6
Prod. Cap. Irrigation Water	kg	6,99	6,99	100
Prod. Cap. Drinking water	kg	6,99	6,99	100
Depletion of reserves	ELU	32600	26200	80,4
Species Extinction	NEX	7,19E-11	6E-11	83,4

Table 32, EPS 2000 Damage assessment

Impact category	Unit	Galix 13	Green Galix	Impact from Green Galix as % of Galix 13 impact
Life Expectancy	ELU	648	479	73,9
Severe Morbidity	ELU	133	99,2	74,6
Morbidity	ELU	20,5	16,6	81,0
Severe Nuisance	ELU	181	156	86,2
Nuisance	ELU	15,7	11,9	75,8
Crop Growth Capacity	ELU	4,76	4,56	95,8
Wood Growth Capacity	ELU	-3,99	-3,14	78,7
Fish and Meat production	ELU	-0,377	-0,292	77,5
Soil Acidification	ELU	0,384	0,294	76,6
Prod. Cap. Irrigation Water	ELU	0,021	0,021	100
Prod. Cap. Drinking water	ELU	0,21	0,21	100
Depletion of reserves	ELU	32600	26200	80,4
Species Extinction	ELU	7,91	6,6	83,4

Table 33, EPS 2000 Weighting

Impact category	Unit	Galix 13	Green Galix	Impact from Green Galix as % of Galix 13 impact
Total	Pt	33600	27000	80,4
Life Expectancy	Pt	648	479	73,9
Severe Morbidity	Pt	133	99,2	74,6
Morbidity	Pt	20,5	16,6	81,0
Severe Nuisance	Pt	181	156	86,2
Nuisance	Pt	15,7	11,9	75,8
Crop Growth Capacity	Pt	4,76	4,56	95,8
Wood Growth Capacity	Pt	-3,99	-3,14	78,7
Fish and Meat production	Pt	-0,377	-0,292	77,5
Soil Acidification	Pt	0,384	0,294	76,6
Prod. Cap. Irrigation Water	Pt	0,021	0,021	100
Prod. Cap. Drinking water	Pt	0,21	0,21	100
Depletion of reserves	Pt	32600	26200	80,4
Species Extinction	Pt	7,91	6,6	83,4

13 Discussion

When analysing Galix 13 F1A the most prominent impact comes from different metals such as brass, steel and aluminium. Without comparison brass (used as an IR obscurant) has the largest impact on the environment. The second largest is steel but it comes rather far behind Brass. The impact from brass is so large that it complicates the analysis because it is difficult to see all the smaller impacts.

When analysing the Green Galix design the same largest impacts as the old design is still seen. This is not surprising since the changes in design are only minimal when it comes to the materials used. The largest reduction is the reduction of brass with 14%, without any reduction in the performance. More use of recycled metals and other smaller reductions gives positive effects. By this the environmental impact reduces with about 10%.

The large change does not come from the exchange of materials but from the exchange of approach. By designing the munitions in a slightly different way it is possible, with minor changes, to extend the life of the munitions from 8 years to 16 years. This gives a significant change in environmental impact. It is seen that the life extension reduces the environmental impact with about 50 % and adding the material changes we have a total reduction of about 50-60%.

What more can be done? Well clearly it is possible to widen the thinking to large changes to the whole of the munitions. That is to look at all the parts and especially look at end of life.

In this study, the only end of life considered is the actual use of the munitions. By adding recycling processes we could still reduce the impact especially from metals.

It has to be said that the largest environmental improvement that can be done on the Galix 13 is to exchange the brass flakes in the obscurant to another material. This would take a very large research effort to find a replacement to brass. Even if it would be possible, it is not decisive that the cost of this would actually benefit the environment.

LCA is a very time consuming tool, and in that way a very expensive tool, mostly because of the data collection. Added to this it is also difficult to evaluate the results and there is a part of the evaluation that is subjective to the evaluator's judgement. This limits the use of LCA, but as a first study it gives a good understanding of what is environmentally important in munitions.

What has been found for munitions is that the metal parts have an overwhelming environmental impact. So with a general knowledge about environmental impacts and the information that are gathered in this and similar LCA it is possible to do generic assumptions about the environmental impact for other munitions. It must be noted that if the munitions are significantly different in concept there could be a need to do similar LCA on those types to make certain that the same assumptions are correct.

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