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From Head to Head: An Emergy Analysis of a War Rifle Bullet

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Abstract:
Emergy (spelled with an "m") analysis is a method for environmental and systemic accounting in terms of sustainability and quality of resources used for a product, service or process. In this paper, it is applied to the assault rifles projectiles used in war battlefields. The specific emergy is evaluated in terms of *sej/bullet*, pointing out the upstream investment made by both the environment and the human society to produce the bullet in its operating war conditions. Comparison is made with alternative uses of the same resources when addressed to the support of development and wellbeing.

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1 Emergy, modern warfare and systemic casualties

Modern conflict analyses are usually carried out within well defined conceptual boundaries, that time after time involve social, economical, political, environmental and religious issues as the driving force able to keep the "warfare system" alive and well. Much less frequent is the use of an integrated systemic approach to describe the complexity of the flows that concur in an armed conflict, as well as its capability to systemically "adapt and survive". In this sense, emergy (spelled with an "m") analysis is among the most comprehensive analytical tools to handle complex systems involving environment, economy and human societies. The term *emergy* derives from "*EMbodied enERGY*", a definition that highlights its conceptual role as some sort of "energy memory". The foundation of emergy analysis is the main outcome of the work by Howard T. Odum (Odum 1987; 1988; 1996; 2007; Odum & Odum, 2006), one of the most creative and productive scientific personalities in the field of systems analysis, who structured and applied the emergy accounting in many disciplines (Brown & Ulgiati, 2004a). The literature reporting the evolution of the conceptual structure of emergy in the last decades is available, together with the complete bibliography of Odum's production, in the website of the *Centre for Environmental Policy* at the *University of Florida*, Gainesville, USA (CEP, 2016). The basic idea is that of expressing in the same unit all the quantities whose flows contribute to the creation and maintenance of a systemic activity, namely, flows of matter, energy and information, to which monetary transactions are added where appropriate. In this way, a quantitative accounting may be set up, thanks to the definition of suitable indicators able to describe the various aspects of the system at issue, pointing out its mode of operation and thus the possible leverage points, criticalities, sustainability and resilience. Emergy analysis was successfully applied to quite a wide range of systems, from the whole geobiosphere (Odum, 1996) to human communities (Lei, Wang & Ton, 2008; Listyawati, Meidiana & Anggraeni, 2014), Countries (Geng et al., 2013), productive sectors (Viglia et al., 2011), ecosystems (Franzese, Brown & Ulgiati, 2014), social sectors (Campbell, Lu & Kolb, 2010), industrial plants (Geng et al., 2010), economic processes (Brown, Cohen & Sweeney, 2009; Brown & Ulgiati, 2011; Campbell & Tilley, 2014). By accounting for all the investments, emergy analysis is in principle suitable to be applied to the description of a whole system as well as of any of its subsystems, at the same time without losing the information on the entirety, in so overcoming the bias of several analyses focused on specific aspects such as the economic, environmental or social ones. In this sense, emergy results also effective in addressing how single aspects or occurrences may be framed as a part of the whole system, contributing to the correct understanding of its mechanisms. In this paper, emergy accounting is applied to the war rifle bullets production, with the aim at determining quantitatively the resources that have to be provided to allow a rifle projectile to do its job.

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The motivation of this study was originated by an episode occurred months ago, when a 7-year-old girl was taken to the *Emergency* NGO (http://www.emergency.it) health facility in Kabul, Afghanistan. Admitted while still alive, she died soon later, due to a rifle bullet stuck into the brain. Episodes like this are usually regarded as side effects, supposedly unwanted by military as well as by politicians and public who promote and endorse, respectively, the armed conflicts. The "side effect casualties" have been addressed in the Geneva Conventions Implementation by the *collateral damage rule* (API, 1977), intended to regulate hostilities such to allow civilian casualties only when they are incidental to an attack on a legitimate military target. This approach is not only ethically questionable, but also factually detached from the reality. As a matter of fact, the overall statistics for war-related deaths assesses a dramatic increase, throughout the last century, of the ratio of civilian to military casualties (Epps, 2013), which is now exceeding the value of 8, despite any claim for modern precise weaponry supposed to allow a "clean", "surgical" war. The Collateral damage rule does not seem to play any role whatsoever, especially in modern conflicts. One reason for this is to be found in the *systemic nature* of the warfare, for which civilian casualties represent a "feature" that the system itself preserves against external perturbations by means of proper self-organizing rearrangements, that are the systemic responses typically acting in order to maintain an operational feature. Civilian dead are not a side effect, but a unique systemic characteristic of modern conflicts. The systemic role played by these casualties is to help guaranteeing that the economic driving forces that fuel the warfare are kept switched on – forces that ultimately rely on the information exchange and on the propaganda boosting the public consensus. Money and resources are then allowed to flow toward the actual end-users of conflicts. Sadly, as observed by Meadows (2008), the purpose of a system is deducible from its behavior, not from the rhetoric or the stated goals. It is interesting to remind that – even from a non-scientific side – the idea to study warfare as an integrated system is dated back to the very early years of systems theory, owing to the work of Kenneth Boulding, who first contributed to the development of general systems theory and to its application to peace and conflicts study issues (Boulding 1962; 1975).

A comprehensive scientific narrative of the bullet history may therefore help to frame the episode within the systemic complexity of a warfare condition, and this is the main purpose of this paper. The assessment is carried out by means of an emergy (spelled with an "m") analysis, that quantifies under the same unit all the investments which made possible the final short trip of the bullet toward the girl's head. The emergy approach provides a novel perspective to non-scientist readers that further points out, even quantitatively, the dreadful senselessness of this overall history. Emergy analysis is an appropriate approach to account for the bullet history, since it is donor-side oriented: instead of defining the "value" of something depending on its utility in terms of user expectations (user-side perspective), it accounts for all the actual resources that must have been made available in order to create the object at issue. This includes direct and indirect nonrenewable energy, materials, human labor and services as well as the environmental inputs to the involved processes. The analysis therefore bypasses the need to embrace any rhetorical claim about *how* to account for the girl's life within the war action, or more generally within the conflict: by addressing quantitatively the upstream costs of the bullet in the girl's head, emergy points out our efforts to create something that in principle could have had whatever different final destiny, thus further underlining the nonsensical aspect of the actual debate about war *management*. In this sense, it must be stressed that a comprehensive integrated evaluation of the costs of conflicts is at the same time mandatory and quite difficult to realize. Indeed, to be effective as a decision-making tool, a real accounting capable of frame the conflicts analysis in a resource diversion perspective must by definition take into account all the intertwined network of flows.

2 The emergy accounting

Emergy analysis derives its symbols and diagrams from the energy language. In fact energy, in its widest conceptual meaning, may be quantitatively assigned to any different kind of flow in as much as it contributes to realize the work which the system is appointed to. All the contributions can be therefore evaluated in terms of energy, and the most natural choice for a "universal" reference is then the solar energy, to which any quantity can be converted by estimating *the equivalent solar energy for its production*, that is the quantity we call *emergy*. Emergy is therefore defined as *the available energy of one kind previously used up directly and indirectly to make a service or product* (Odum, 1996). It is not a state function, since the emergy of something depends on the processes which created that something, also accounting for the time needed in the generation process. Its unit is the *solar emjoule* (*sej*), indicating that solar energy is chosen (as usually is) as the reference form. The solar energy may be so considered as a baseline, used for assigning a common quantitative unit, similar in that to the use of *TOE* (tons of oil equivalent) to measure big quantities of energy even when it does not come from oil burning.

The general methodology for emergy accounting starts from the setting up of a diagram of the system at issue (Brown, 2004). The diagram will contain all the stocks/storages, flows and processes that define its operation. Then, an inventory table is prepared reporting quantitatively all the flows. By using specific transformation coefficients for each quantity, all flows are expressed in the same (emergy) unit, allowing to calculate a series of indicators in order to obtain from the analytical outcome the desired information. The transformation coefficients are called *UEVs*, *Unit Emergy Values*, that are the emergy required to generate one unit of output of a certain product, be it mass, energy, work, money, and so on. *UEVs* are therefore a measure of how much must be invested to obtain an output unit. *Transformity* (in *sej/J*) is the *UEV* for energy, indicating the emergetic input per unit of energy available at the output. Given a certain product obtained from different processes, a lower transformity value indicates a higher efficiency in terms of necessary inputs per unit of output, efficiency that is totally uncorrelated to the economic one. Other *UEVs* are the *specific emergy*, that is the emergy per unit of mass of output (*sej/g*), and the emergy cost of labor, allowing to quantify the emergy supporting a unit of labor directly supplied to a process. It is expressed in either *sej/$* (*sej* per unit of money earned) or in *sej/h* (*sej* per unit of time). The *emergy per unit money* is in turn defined as the emergy related to the generation of a unit of economic product, expressed in the proper monetary currency and used to convert the monetary transactions into emergy units, so representing the quantity of emergy associated to the purchasing power of a given currency. As a matter of fact, the amount of resources related to the purchasing power of a currency depends on the amount of money supporting the local economy as well as on the circulating amount of money. An average estimate of the emergy per unit money may be therefore obtained by computing the ratio between the total emergy used by a Country and its Gross Domestic Product. In this way, for each Country a parameter can be calculated suitable to evidence the inequality of a trade with another Country, when for example a flow of emergy associated to some resource is not balanced by a corresponding flow of emergy associated to the money that buys that resource. Indeed, the emergy/dollar ratios are higher in the less developed Countries than the developed ones, and the raw resources bought by developed countries carry much more real wealth than is paid for [see Odum (1996)for a comprehensive presentation of this issue]. Actually, the possibility of converting money flows into the same unit of materials and energy flows represents one of the main issues for the emergy accounting method, in so far not only policy-makers can use it for addressing the sustainability of the resources trade, but also because it allows to define a suitable benchmark for socio-economic systems. As for the presented study, a widening of the system boundary would be required to focus the analysis to case of the arms trade industry, for which an emergy-based evaluation of the complex network of trading appears mandatory for a correct identification of the role played by the various actors in conflicts.

Figure 1shows the emergy diagram for a generic productive process. Solid arrows indicate the flows of matter, energy, information, etc. whereas dashed arrows indicate the money flows; arrow-shaped units in the upper part of the figure indicate the occurring of a process that transforms and controls a flow. A heat sink is also included (grounding symbol) representing the material resources and heat irreversibly lost due to the second principle of Thermodynamics.

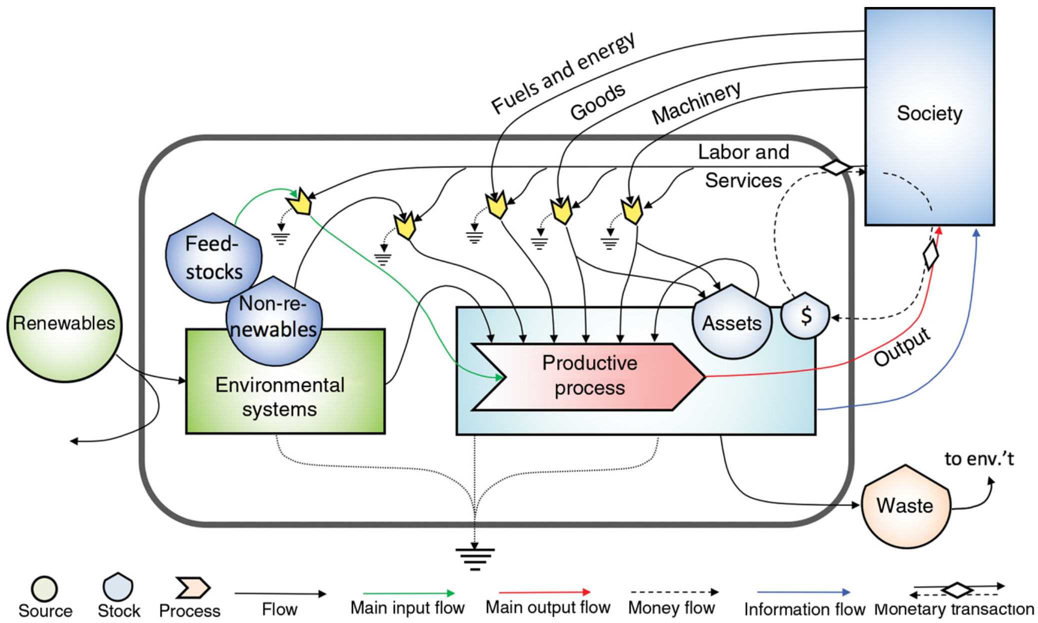

Figure 1: Emergy diagram for a generic productive process.

It is worth remarking that the money flow is the only one to be circular, triggering the flows of resources and the occurrence of the related processes and transformations involved in the overall production process. It should be noted that money is only exchanged with labor and services, the latter including all the materials, energy, and labor that were necessary to make or deliver fuels and energy, goods, and machinery. For example, when buying a liter of oil, one is not paying *the geobiosphere* for its supply, but *the people* responsible for all the processes that allowed its extraction, refinement and transport, occurred before entering the system at issue. The definition of the diagram boundary is the very first step of an emergy analysis, to assess what are to be considered the inflows and outflows, and what should be ascribed to sub-processes occurring within the system boundary. Boundary must be defined in both spatial and temporal scales, in order to make the specific flows homogeneous for the quantitative accounting. The inventory table is built up reporting the values per unit time (typically one year) of all the respective flows (fuels, materials, energy, labor and so on) along with the corresponding *UEV*, to get in the last column the emergy for any flow. By the rules of emergy algebra, one can finally develop the quantitative analysis and the calculation of the emergy indicators, which range from those specifically related to environmental issues of sustainability, resilience and impact, to those integrating socio-political and economic aspects. Reviews of the several emergy indicators may be found in (Brown & Ulgiati, 2004b).

3 The analysis of the bullet

A small arm projectile has a structure like that showed in Figure 2. It is composed of two main metal parts, one forming the cartridge that contains the propellant and the other one, on the front part, being the actual bullet. Each part may be done with different metals, but the most common are made by lead or tungsten-tin/zinc (bullet) and by brass or copper (cartridge case and bullet jacket). On the other hand, the cartridge case and the primer of a small arm projectile may contain dozens of different chemicals, which are mixed at the factory plant and depend on the type of bullet and the desired performances. The details of the chemicals present in the projectile may in turn vary depending on the weaponry, but what is interesting in our approach is the overall involvement of global trades in the ammunition fabrication.

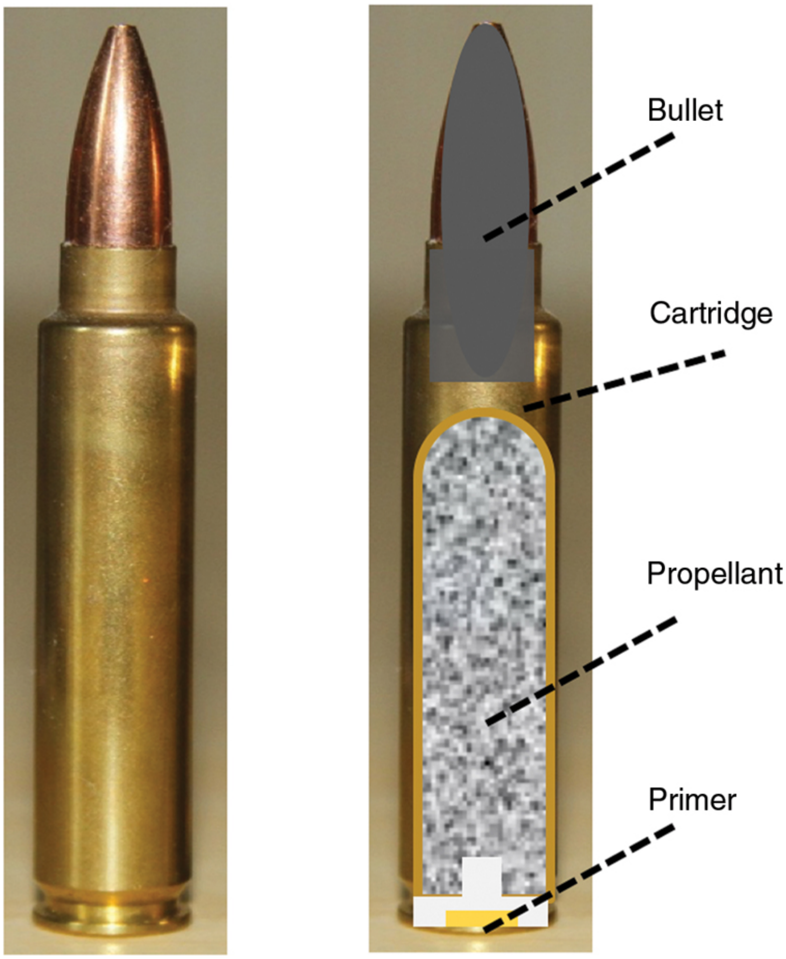

Figure 2: Projectile structure.

The origin of metals and chemicals used in a typical US ammunition plant for a projectile fabrication (Siekman, Anderson & Boyce, 2010) may involve imported bullet and cartridge constituents from India, South

America, Russia, China and Australia, while the chemicals found in the primer are mainly from European Union, Brazil, China and United States. Even without carrying out a detailed quantitative account, clearly appears that a manufacturing requiring resources from different continents represents a global investment whose actual dimension is hard to appreciate whatsoever.

The economic system invests energy, goods, labor and services in the exploitation of the resources, whereas economic activities and sectors (mining, industry, education, transportation, etc.) in turn provide products and services. Figure 3shows the diagram describing the overall system supporting the bullet production, from the mineral extraction to the market allocation of the product. The environmental driving forces are linked to the work done by the nature for cycling and concentrating resources, including minerals. The overall process of bullet production benefits from an ecosystem that provides all the natural services (usually, never accounted for in economic analyses) and receives waste and pollution, which are later partly absorbed and dispersed, and partly accumulated until degradation. Feedstocks enter the system in different forms, and are processed and transformed into projectiles (red path in Figure 3) thanks to contributions that are typical of a production plant for which renewable energies play a negligible role in the process. However, a significant contribution of the environment may intervene downstream, in the form of environmental services provided to dilute the pollutants released during the fabrication process. Raw data are converted into emergy units, and then added up into a total emergy flow for the system, avoiding double counting. As is typical of the evaluation of a process, data refer to flows per unit time (usually per year). Global emergy baseline of the geobiosphere is set to 1.2E+25 *seJ/year* (Brown et al., 2016). Table 1shows the actual flows related to the bullet fabrication. It is important to stress that the accounted flows refer to the bullet production subsystem, indicated by the red boundary in Figure 3, so neglecting the contribution of renewables (however minor) as well as the extraction of minerals, and thus focusing in the final part of the process. In particular, items 13 to 15 refer only to this last step.

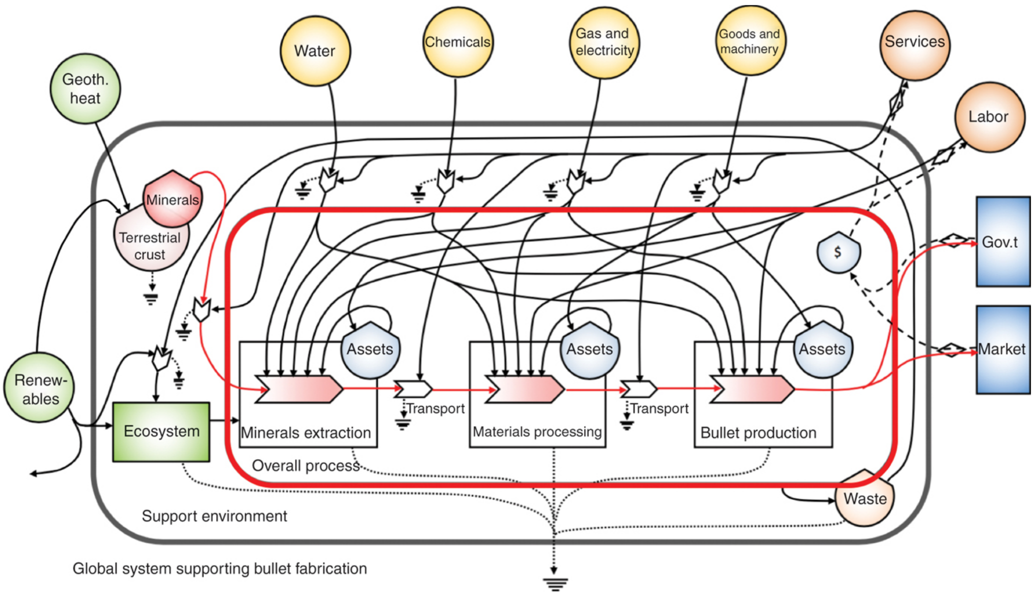

Figure 3: Emergy diagram of the system supporting the bullet production.

Table 1: Emergy accounting for the fabrication of an ammunition.

#	Item	Amount	Unit	UEV (sej/unit)*	Ref.	Emergy (sej)
Materials						
Cartridge						
1	Brass	4.90E–03	kg	1.17E+13	[a]	5.73E+10
Bullet						
2	Steel	3.90E–03	kg	1.48E+13	[a]	5.79E+10
3	Lead	6.10E–03	kg	1.69E+12	[a]	1.03E+10
4	Antimony powder (as antimony)	9.50E–05	kg	1.54E+13	[a]	1.47E+09
Primer						
5	Brass	2.40E–04	kg	1.17E+13	[a]	2.81E+09

6	Antimony sulphide (as stibnite)	1.30E–06	kg	1.14E+13	[a]	1.48E+07
7	Lead dioxide (as lead)	1.30E–06	kg	1.69E+12	[a]	2.20E+06
8	Calcium silicide (as mineral, wallostanite)	1.30E–06	kg	6.98E+10	[a]	2.81E+04
9	Explosives	1.62E–05	kg	4.96E+12	[a]	8.03E+07
Propellant						
10	Smokeless powder	4.10E–04	kg	1.07E+12	[a]	4.38E+08
11	Cardboard	3.20E–04	kg	3.08E+12	[b]	9.85E+08
Machinery						
12	Industrial machines	4.76E–03	kg	5.56E+12	[a]	2.65E+10
Energy and water requirement						
13	Electricity	4.60E–02	kWh	5.46E+11	[c]	2.51E+10
14	Natural gas	2.40E–01	MJ	1.40E+11	[d]	3.36E+10
15	Water	2.04E+00	kg	1.00E+08	[d]	2.04E+08
Labor and services						
16	Labor	1.08E–01	€	7.58E+11	[e]	8.20E+10
17	Services for the supply of material inputs	6.53E–02	€	7.58E+11	[e]	4.95E+10
18	Services for the supply of machinery	1.59E–02	€	7.58E+11	[e]	1.20E+10
19	Services for the delivery of energy & water	1.54E+00	€	7.58E+11	[e]	1.17E+12
Weight of the bullet (lines 2 to 4 only)		1.01E–02	kg			
Total weight of the ammunition		1.60E–02	kg			
Emergy of bullet fabrication						
	Specific emergy (in sej/bullet), with labor and services			1.53E+12 sej/bullet		
	Specific emergy (in sej/kg), with labor and services			1.52E+14 sej/kg		
	Specific emergy (in sej/bullet), without labor and services			2.17E+11 sej/bullet		
	Specific emergy (in sej/kg), without labor and services			2.15E+13 sej/kg		

[a] Calculated for this work, calculation tables are not reported**; [b] Almeida et al. (2013); [c] Brown and Ulgiati (2002); [d] De Vilbiss and Brown (2015); [e] Buonocore et al. (2015).
*Calculated or converted from previous works, according to the GEB_{2016} of 1.20 E+25 sej (Brown et al., 2016).
**UEVs of raw materials or products as available on the market (i.e., including extraction, processing and transport).

Besides the accurateness of the inventory, the reliability of the emergy analysis is based on that of the *UEVs*, which are either obtained from previous works or calculated purposefully. For any item, it is also possible to calculate the corresponding emergy-related currency equivalent, obtained by dividing the emergy of the item by the emergy/GDP ratio for the country and the chosen year, calculated independently. This expresses the amount of economic activity that can be supported by a given emergy flow, within the economic system under study. The items used in our work to perform the final calculation are actually almost 300 (not reported here), and include all the details about the materials synthesis, the average costs for supply and delivery of materials and machinery as well as those for processing to the final product. In Table 1, these data have been grouped in categories, in order to point out where the major contributions to the emergy of the bullet come from.

Materials as well as energy and water requirements for the bullets fabrication were taken from Ferreira et al. (2016), who applied the *Life Cycle Assessment* (*LCA*) methodology to different *9-mm* ammunition projectiles, used as a reference for all the quantities of energy and materials involved in the fabrication of the bullet at issue since they are actually totally comparable from the points of view of both the production process and the materials used. Data on the machinery and man-hours work necessary for bullets production line were taken from commercial American companies (Caina-Longbranch, 2016), whereas the salaries for the involved personnel were calculated taking the average values for each job as reported by PayScale site (PayScale, 2017). All inputs were processed using Ecoinvent 3.1 LCA (Wernet et al., 2016).

4 Discussion

4.1 The emergy of the bullet

As clearly indicated by the values of emergy contributions reported in Table 1, the most relevant ones are labor and services, whereas those related to the materials and chemicals are – somewhat surprising – almost negligible, despite their high technological features. This confirms that the investment necessary to operate the production process of the ammunition industry is driven mostly by technology and know-how (skilled designers and engineers, laboratories, and so on) rather than raw materials. Information related to know-how and technology is actually very expensive in terms of resources consumption, giving rise to a much higher requirement for resources by the weaponry industry compared to other sectors, such as for example food production. On the other hand, the ammunition industry does not make more emergy available to society than invested, thus not providing a net emergy return to the economy. For instance, human activities such as oil extraction or fishery exhibit a positive emergy return, in that their products contain more emergy than that invested, since for both sectors there is much emergy provided "for free" by Nature over time (million years for oil, years for fishes) that is collected thanks to a small resource investment. On the contrary, bullets do not make new emergy available, requiring resources only to destroy highly organized forms (life, cities, lands) and therefore wasting the emergy stored in these forms.

Besides the scientific information brought by the obtained specific emergy value, be it in *sej/kg* or in *sej/bullet*, a useful insight is possible when this is compared to other production activities that one can more easily frame within the peacetime everyday life. For example, the emergy virtually contained in a bullet is about the same of 5 kg of sweet potatoes served in a US restaurant (Campbell, Wigand & Schuetz, 2015), roughly corresponding to 4300 kcal of energy provided to the user. Considering that about 500 firearm bullets are produced per second (Amnesty International, 2015) worldwide, it is frightfully easy to account for how many people could be fed and could survive during a wartime with the investment (in *sej*) that is actually dedicated *in one second* to the production of ammunition.

The obtained *sej/bullet* value represents the quantitative memory of what the Society made, with the contribution of the geobiosphere, in order to let a bunch of highly organized and concentrated metals enter the head of a girl in the form of a bullet, and kill her. Bad indeed, but it becomes much worse by considering that, from the user-side viewpoint, this is quite a good economy booster factor, given that the annual production of firearms bullets, part of a total global military expenditure of more than 1.5 trillion USD in 2014 (SIPRI, 2015), is of about 15 billion units (Amnesty International, 2015). This just means that in the time it takes you to finish reading this phrase, some thousands new bullets have entered the global market. Again, this points out the real systemic dynamics that rules the warfare management.

4.2 From the head of an engineer to the head of a girl

This paper aims mainly at providing a conceptual tool for better comprehending what is actually happening, but further insights are also suggested. It addresses the "classical" topic about the potential role of science and scientists in the conflicts. This role has been enriched by new aspects, since the modern warfare requires a systemic perspective to be correctly described (Gallo, 2012), and – along with the "traditional" responsibility of their contribution to the technological advancement of weaponry– the scientists have now the increasing responsibility of providing a factual lowdown of the reality toward both the decision makers and the public. In this sense, emergy analysis is one example of how science can contribute to the understanding and the diffusion of correct information about global issues such as warfare. It allows additional costs and losses to be properly considered and quantified, so making the assessment much deeper and complete. The different possible levels of the analysis, that in turn depend on the boundary definition, address a comprehensive insight on the resources flow at different scales, both spatial and temporal. Even without entering the quantitative details for most of the analysis scales, the presented bullet diagrams help to frame the huge variety of investments that support an armed conflict, investments that are ultimately connected with the systemic self-organized economy which warfare is based on. Emergy diagrams allow to point out the crucial role of the exchange of information, that in fact starts when the society invests in the education of creative engineers who design new weaponry, which in turn includes the bullet at issue, virtually travelling from the head of an engineer to the head of a girl.

4.3 Environmental issues

Emergy accounting is usually dedicated to either ecological or productive systems, so that the downstream costs are usually computed as the actual work done by the environment for the dilution of pollutants, and/or that done in the human-controlled processes necessary for waste disposal or emissions treatment. In the case of the projectiles at issue, this calculation is extremely difficult since it strongly depends on the specific situation, and this will be the object of a much needed second step of this study (Ulgiati, Zucaro & Franzese, 2011). The overall cost of a bullet is anyway even more unbearable when considering the downstream costs the society has to support after the ammunition has been used in the battlefield. A second step of analysis for sustainability assessment, in the perspective of preserving the capacity of future generations to meet their own needs, will require that reconstruction and restoring of the territory are taken into account as an actual cost (see for example: http://legaciesofwar.org/about-laos/secret-war-laos/). A calculation of the environmental impact of the use of small-arms projectiles in warfare has been recently addressed by Ferreira et al. (2016)in terms of environmental and toxicological impact of the substances involved in a gunshot, aimed at contributing to the "green ammunition" technological development.

"Green bullet" is the nickname for a US Department of Defense program started in the late nineties, aimed at eliminating the use of hazardous materials from small arms ammunition, that should be made [literally, from Dilnot (2014)] "good for the environment but still deadly when used properly". This allows soldiers in Iraq and Afghanistan to fire *eco-friendly* rifle bullets, that at the same time "cause more bodily harm than the lead bullets they replaced" (Wittenberg, 2015). The very idea of (verbatim) "non-toxic small arms projectiles (...), tough on enemies but easy on mother earth" (Mikko, 2000) seems to be a TV comedian joke: a "toxic material", for the Webster Dictionary, is one capable of causing death or serious debilitation. Needless to say, any *trustworthy* account of the impact of systematic war weaponry use in a territory points to the "easiness on mother earth" as a plain mockery of reality. As a matter of fact, the overall damage to the ecosystemic, social and economic environments in warfare condition has nothing to do, upon any metric, with replacing *lead bullets* with *eco-friendly tungsten-tin* ones, or *diazodinitrophenol* with *antimony trisulfide* in the cartridge primer.

A comprehensive calculation of the environmental effect of an armed conflict and, within this, of the use of hundreds of thousands of assault rifle bullets may be certainly addressed in terms of downstream pollution due to the emissions at the gunshot and to the materials dispersed in the environment. On the other hand, it appears evident that ecosystemic equilibrium and balance is going to be much more affected by projectile use through its consequences on the society and on the infrastructures, and this further indicates the emergy analysis as a possible way to account for the real impact of warfare conditions on the environment.

5 Conclusions

An emergy analysis has been carried out in this study for a typical war rifle bullet used in modern conflicts. This study was suggested by a war episode recently occurred in the health facility of the NGO "Emergency" in Kabul, Afghanistan, where a young girl was taken with such a bullet stuck in her brain. The analysis aims at providing a quantitative accounting of the overall investment that supports the fabrication of a rifle ammunition in terms of materials, energy and human labor resources. This has been realized by means of the emergy synthesis, an approach that allows to compute all the flows of resources entering the production processes in the same unit. The main conclusions are then:

-- Through its emergy, a bullet carries the memory of a hugely diversified investment, involving several resource flows coming from geographical locations covering half of the planet.

-- The value of the bullet emergy resulted of 1.53E+12 *sej* (labor and services included), comparable to that of 5 kg of potatoes as served in a US restaurant.

-- Human activity contributions play a major role in the accounting, addressing how the ammunition fabrication – and thus its market – are strongly based on labor and services economy.

-- Given the bullets fabrication rate worldwide, the emergy virtually carried by the ammunition addresses a quite relevant global cost, much more remarkable than the corresponding monetary one.

-- The comparison with other goods requiring the same emergetic investment may tell a very clear history about the global resources allocation, addressing the potential effectivness of emergy analysis of resource diversion options.
-- The un-sustainability of the bullet is further underlined by considering also the downstream effects of ammunition use, devastating for local societies and environment. In this sense, an emergy analysis of the warfare phenomenon mechanisms will be addressed in future works.

A general conclusion can be addressed concerning the possible role of emergy analysis in peace and conflict studies. As a systemic analysis, emergy accounting presents some major advantages with respect to more traditional analyses, focused time after time on specific aspects. By converting all types of flows in the same unit, the analysis can take quantitatively into account the contributions of labor and services as well as those of environmental services (both up- and downstream), that are typically left out when an environmental or an economic balance appraisal is performed, respectively. The potential capability of emergy analysis to include in the accounting intangible goods (one for all, information) makes it a quite powerful analytical tool wherever a system operation lies also on the exchange of huge quantities of information, such is the case of warfare. In the case of arms industry, an emergy evaluation can be useful to clarify how much the arms trade contributes to keep the "warfare system" operated in terms of emergy flows, a quantitative evaluation that is intrinsically comparable to the same evaluation performed on any of the subsystems involved in warfare. The *Systems Thinking* attitude appears crucially important to understand how things like the described bullet history keep happening. As H.T. Odum said, "diagramming helps us consider the great problems of power, pollution, population, food, and war free from our fetters of indoctrination" (Odum, 1971), pointing out the emergy analysis as a cultural tool of enormous potential even in peace studies.

A final comment is suggested concerning the dissemination of a modern scientific approach, which appears mandatory to address a systemic interpretation of conflicts at both local and global levels (Ulgiati, 2004). Somewhat surprisingly, an increasing awareness of this comes even from the military world: as observed by Greenwood *et al.* in the *Armed Forces Journal* (Greenwood & Hammes, 2009), "warfare has always been interactively complex" and "the current doctrinal definition of operational art is simply inadequate". In the same article, the problem of humanitarian relief is also explicitly addressed, underlining the need for outside experts (such as health specialists, religious scholars, women's rights advocates, anthropologists) to integrate the military joint planning groups, an approach that recalls at least a systemic awareness of the complexity of the issues. Finally, the authors explicitly claim that quite few complex structured problems are actually military-centric in nature. They are rather "driven by political corruption, disease, resource deprivation, overpopulation, urbanization, illiteracy, refugees, globalization, extremist ideology or some combination thereof that create conflict and instability". This, in our opinion, further confirms that if an effective culture of peace has to be set up, scientific approaches like that discussed in this paper should be strongly pursued even outside the scientific community.

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