Healthcare waste and extended producer responsibility: the specific case of e-medical equipment

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Abstract— The extended producer responsibility implies more than the mere take-back and recycling programs tailored towards the end-of-life management. It requires the producers to design products that are environmentally friendly during all stages of their life cycle, namely manufacturing, usage or consumption, and final disposal. In particular, it implies that products at the end of their useful life should be easily dismantled, recovered, reused, and recycled. This paper examines how the producers of electronic medical equipment (e-medical equipment) attempt to reduce the environmental impacts of their products during its entire life cycle through different initiatives. The main objectives are as follows: to gain a better understanding of these environmentally proactive initiatives, to assess their relative importance, to analyze the main drivers and to examine the key benefits that are derived from such initiatives.

Keywords— *Electronic waste, healthcare, environmental initiatives, electronic medical equipment, extended producer responsibility.*

I. Introduction

The World Bank has estimated that approximately 5.2 million people (including 4 million children) die each year from waste-related diseases. Healthcare waste is particularly under scrutiny because of its severe adverse impacts on human health and the environment. This paper focuses on one type of healthcare waste, namely the electronic medical equipment (e-medical equipment). Although the trend towards electronics and digitalisation is omnipresent in healthcare activities, the issue of e-medical equipment remains largely under investigated in the literature. Because environmental problems at the end of life of e-medical equipment start with the products themselves, we have opted for a "product centric" approach which is in line with the concept of the extended producer responsibility, also known as product stewardship. We thus analyzed the initiatives undertaken by the e-medical equipment manufacturers to reduce the environmental impacts of their products when they are manufactured, used and finally disposed (when they become obsolete). We will present here empirical evidence gathered from e-medical equipment producers located in the US and Canada. The specific objectives are as follows: 1) to gain a better understanding of the initiatives undertaken by the e-medical equipment producers to green their products, 2) to assess the relative importance of such initiatives, 3) to analyze the main drivers of these initiatives and 4) to examine the key benefits derived from these initiatives.

The next section (section 2) gives an overview of healthcare waste in general and discusses the specific issues related to e-medical equipment. Section 3 exposes the research design while section 4 offers a discussion of the empirical results obtained from 59 producers of e-medical equipment. The paper concludes with the contributions and implications that can be derived from the empirical results.

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II. Waste Management in the Healthcare Sector

A. Healthcare waste

The healthcare sector produces huge amounts of waste. For instance, the healthcare sector in the US constitutes the second largest source of waste after the food industry [1]. In fact, American hospitals generated 2 million tons of waste in 2005 [2], [3]. The waste generation rate varies between 1,5 and 3,9 kg/bed/day for North American hospitals and between 3,3 and 4,4 kg/bed/day in Western European hospitals [4]. The waste generation rate in the healthcare sector follows an upward trend due to a number of factors such as an aging population, a wider access to healthcare services and a greater reliance on disposable and individually wrapped and pre-packaged one use only medical devices.

Healthcare waste has been broadly classified into non-clinical and clinical waste. Non-clinical waste refers basically to ordinary trash and is similar to the waste produced by any home, hotel or office. It includes residual material such as obsolete electronic equipment, paper, cartons or discarded food [5]. Non-clinical waste represents approximately 80% of the waste produced by healthcare organizations and is typically considered as not dangerous. The remaining 20% is clinical waste and is highly regulated. It refers to any waste which consists wholly or partly of human or animal tissue, blood or body fluid, excretion or any chemical product. It also includes discarded cultures, stocks of infectious agents, associated microbiological, pathological wastes, radioactive, chemical or pharmaceutical products, used and unused discarded sharps, animal waste, human blood or blood products [6]. This waste, considering as dangerous, requires special waste management procedures (collection, segregation, storage, transportation, treatment and disposal) to prevent any negative impact on persons or environment [7].

B. Healthcare waste management

Healthcare waste management has been heavily criticized, especially since the wash-up of medical wastes on the New-York and New-Jersey beaches in the late 80s. These incidents have raised a public outcry and provided the impetus for more adequate waste management procedures in healthcare organizations. However, these procedures are still considered as "disappointing" in industrialized countries [8, p.1] and unsafe in developing countries [9]. For instance, the inadequate disposal of contaminated syringes and needles entails serious health risks to healthcare workers, waste handlers, patients and the general public. The World Health Organization estimates that contaminated injection equipment have caused, in 2000, 21 million hepatitis B virus (HBV) infections, two million hepatitis C virus (HCV) infections and 260 000 HIV infections [10]. In general, current waste management activities have to be improved and should capitalize on waste minimization and waste valorization opportunities (material recovery, recuperation and recycling) [11].

C. The specific issue of e-medical equipment

Based on the results of a field study conducted in four hospitals, it has been recently suggested that a specific waste stream, namely the unwanted e- medical equipment, is becoming increasingly important in the healthcare sector [11]. This study demonstrates that an astonishingly high number and a wide variety of electronic devices and equipment are used on a daily basis by physicians, healthcare specialists, nurses, pharmacists and support medical staff. Indeed, e-medical equipment is omnipresent in healthcare facilities for all main activities of patients care, namely evaluation, treatment, and monitoring (Figure 1). E-medical equipment ranges from expensive, complex and costly equipment such as imaging systems, laser equipments, hematologic systems or surgical machines to everyday medical devices such as digital thermometers or sphygmomanometers (commonly known as blood pressure meters).

E-medical equipment brings important benefits to both patients and healthcare workers [12]. In fact, the introduction of more sophisticated e-medical technologies ranging from electronics, digitalization and remote access to emergent

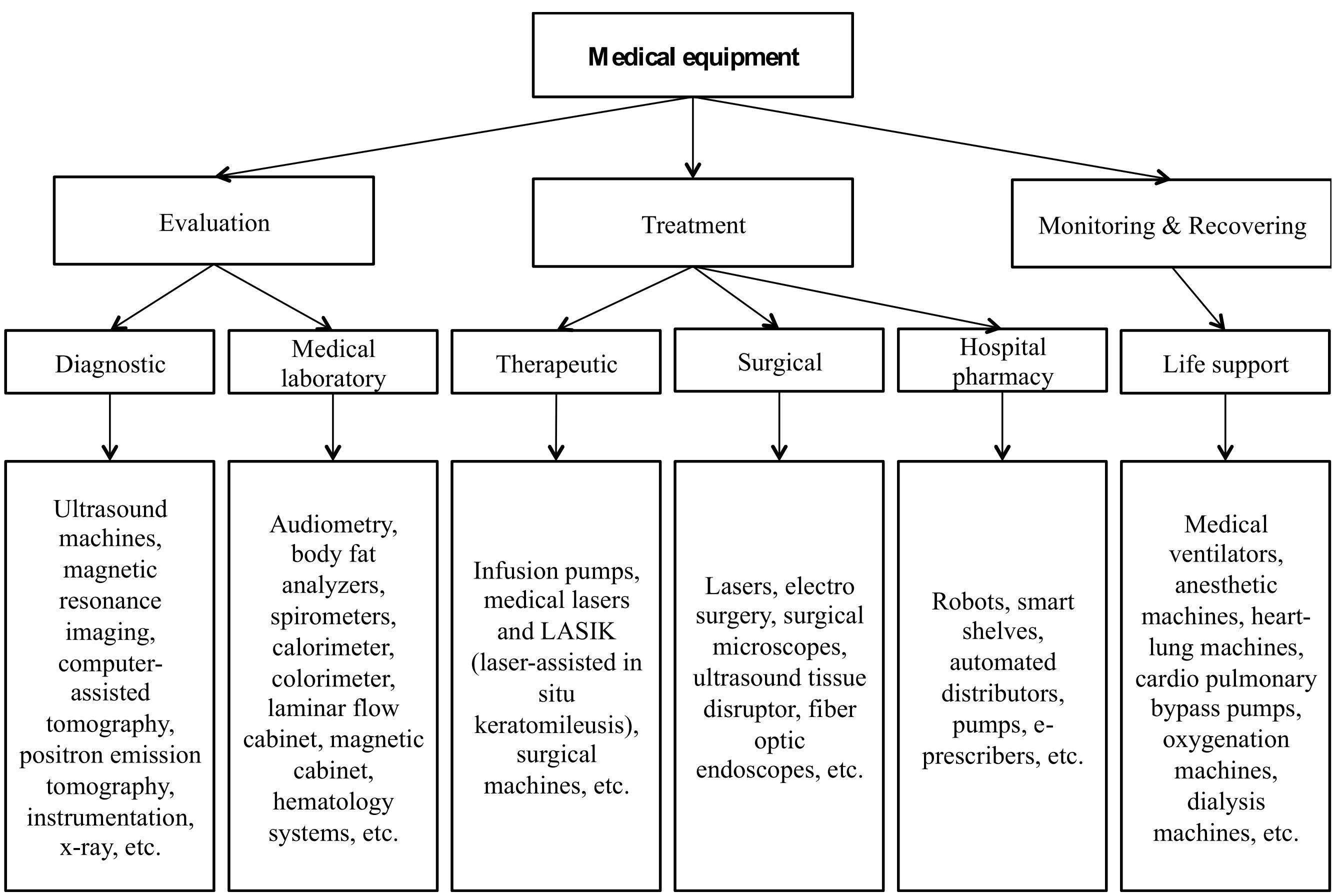

Fig. 1 Classification of e-medical equipment and some examples Source: adapted from [6].

technologies such as magnetic resonance imaging magnetic, nanotechnologies, RFID or infrared technology is largely responsible for the improvement and quality of healthcare services [13]. However, the final disposal of this large variety of e-medical equipment has a negative impact on the human health and environment. Because medical electronic equipment may be infected or contaminated with human or animal tissues, body fluids or chemical products, it cannot be treated as “regular” e-waste such as obsolete computers and related peripherals.

E-medical equipment, just like many electronics products, contains hazardous constituents, like lead in cathode ray tube monitors, chlorinated plastics in cable wiring, brominated flame retardants in circuit boards and plastic enclosures, and mercury in liquid crystal displays [13]. Several studies have shown that these constituents, if they are not properly treated, incinerated or buried, can represent a danger to the public health and are linked to cancer, birth defects, and hormone disruption and affect the coronary, respiratory, nervous and skeletal system functions [14]. For instance, inadequate incineration of plastics containing brominated flame retardants releases polybrominated dibenzodioxins and dibenzofurans that are highly toxic in small concentrations, are very persistent in the environment and omnipresent worldwide, even in remote areas such as the Arctic, and are found in increasing levels in sediments, marine animals and humans [15], [16].

Lefebvre and co-authors [11] analyzed the main initiatives undertaken by hospitals to deal with unwanted e-medical equipment, namely environmentally conscious purchasing, proper segregation of waste, reprocessing, reuse and recycle options, and reducing the amount of e-waste. First, *environmentally conscious purchasing* is the preferred option to acquire new e-medical equipment. However, budget constraints are very present while innovative purchasing procedures such as taking into account the total costs of owning equipment and, in particular, anticipating the disposal costs, do not seem to be a widespread practice. Second, *proper segregation of waste* represents both an environmentally sound and cost effective solution for unwanted e-medical equipment. But, once clinical and non-clinical waste is mixed together, it is treated as clinical waste and has to be eliminated by regulated and expensive methods, such as incineration, autoclaving, dielectric heating, or microwaving. Health professionals and support staff point to the lack of time, an inadequate awareness and an inadequate waste identification as the main obstacles to a more appropriate segregation of waste. Third, *reprocessing, reuse and recycle* seem appropriate for the large, sophisticated and costly e-medical equipment such as the magnetic resonance imaging systems but not for the smaller and rather inexpensive medical devices such as the digital pulse oximeters. When equipment is donated to charitable or humanitarian organizations, it may face some liability issues and entails logistics issues, especially for large medical equipment. Furthermore, the disposal problems are only postponed for a few years. The main obstacles related to reprocessed e-medical equipment appear to be difficult to overcome since they deal more with emotions than facts, namely the “feeling that the reprocessed equipment is still dirty or infected even after being properly treated”, the “reluctance of patients to be treated with refurbished equipment” and the perception that “reprocessed equipment might malfunction” [11 p. 10].

D. Extended producer responsibility: the specific case of e-medical equipment

From the above discussion, current waste management initiatives with respect to e-medical equipment seem to be ill-fitted to the current context of healthcare organizations in general and hospitals in particular. There is a general consensus that the responsibility to reduce the environmental impacts of a product during its entire life cycle should be placed on the producers and this is reflected in current environmental policies [17]. This trend known as the extended producer responsibility and also termed product stewardship, implies more than the mere take-back and recycling programs tailored towards the end-of-life management [18]. It requires the producers to design products that are environmentally friendly during all stages of their life cycle, namely manufacturing, usage or consumption, and final disposal [19]. In particular, it implies that products at the end of their useful life should be easily dismantled, recovered, reused, and recycled. According with EU members, producers must establish product stewardship as competence core for ensuring their competitive position [20] and reducing their production cost [21].

Because e-waste represents a serious environmental issue, the extended producer responsibility approach has been implemented, at least to some extent, to the electrical and electronic equipment. The European Community directive 2002/96/EC on waste electrical and electronic equipment (WEEE) imposes the responsibility for the disposal of waste electrical and electronic equipment on the manufacturers of such equipment at end-of-life. The WEEE directive does not apply to “implanted medical equipment and infected medical equipment”. Some producers such as Baxter require a decontamination certificate for medical equipment before it can be collected for recycling (see for example, http://www.baxter.eu/directives/weee/netherlands.html).

In addition to the WEEE directive, the EU directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) requires that heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame retardants are banned or limited in new electronic products. E-medical equipment represents one of the ten categories of products covered by the WEEE directive (category 8- medical devices). The RoHS Directive is currently being revised and seems to exclude category 8 until January 1, 2014 and the in vitro medical devices until January 1, 2016. Similar legislation, although in general less stringent than the EU legislation, exists in the U.S. and Canada. For instance, at the end of year 2010, 24 states in the US have implemented legislation for e-waste recycling [22] and these states have retained the extended producer responsibility approach, the only exception being California that collects an e-waste recycling fee from consumers. State legislation also bans or restricts hazardous substances, in particular mercury and flame retardants (penta- and octa-bromodiphenyl ether).

Legislation in the EU, the US or Canada has been extensively debated and revised. According to some observers, the EU legislation does not "keep up with mounting e-trash" [23] and the initial ambitious targets are becoming "modest" [24]. Similar comments are arising in the US and Canada. Furthermore, e-medical equipment seems, at worst, to fall into the "cracks of the legislation" or, at best, represents a specific case that tends to be delayed. This leaves us with unanswered questions: Are the producers of e-medical equipment environmentally proactive? Do they embrace the extended producer responsibility approach? The remaining part of this paper attempts to answer these questions.

III. Methodology

A. Data collection strategy

Recent empirical evidence [11] and the extended producer approach [17, 18, 19] suggest the producers of e-medical equipment play a central and critical role in reducing the environmental impacts of their own products. A survey was therefore conducted among the producers of e-medical equipment. The pre-tested questionnaire with a covering letter explaining the research context and assuring complete confidentiality were sent to three respondents in each firm: the CEO (chief executive officer) because of his/her overall knowledge of the strategic orientation of the firm, the head of operations/manufacturing, and the marketing director. Multiple respondents seem to be highly appropriate for two main reasons: first, the data are more reliable than they would have been with a single informant [25] and second, an effective environmental strategy requires a functional integration [26].

The goodness of fit tests indicate that non-responding firms do not differ significantly from responding firms with respect to both firm size and the type of e-medical equipment. Due to the presence of multiple respondents, inter-rater reliability tests [27] were also conducted in order to assess the existence of particular biases among the different types of respondents (CEOs, heads of operations/ manufacturing, marketing directors). Based on the inter-rater reliability tests, the information given by the respondents ranges from very reliable (r =0.97) to reliable (r = 0.59), with only the exception of one firm which is removed from the data base.

B. Research variables

The questionnaire included four broad sets of variables that are mainly based on a detailed literature review and validated from on-site semi-structured interviews carried out in five firms producing and manufacturing e-medical equipment.

The first set represents some organizational characteristics such as firm size, their customers, their products and the environmental programs they have implemented.

The second set of variables refers to a list of 15 potential initiatives that could be undertaken by producers in order to reduce the environmental impacts during all stages of their products' life cycle, including the disposal of unwanted e-medical equipment. The theoretical justification of these initiatives is provided in Appendix 1. As displayed in Figure 2, we propose that these 15 initiatives may be divided into three subsets. Initiatives in the first subset have a direct impact on the producers themselves while initiatives in the second and third subsets may also have an impact downstream, i.e. on the healthcare organizations that use the equipment and on the waste management organizations that 1) transport, 2) treat, decontaminate or disinfect and 3) segregate of e-waste components into recovery materials and waste materials, valorize the recovery materials, or incinerate or bury in sanitary landfills. The relative importance of the initiatives in each subset will allow to determine if they are more related to the organizational and environmental performance of producers (first subset), to the needs of their customers, namely the healthcare organizations including the hospitals (second subset) or to the increasing pressures to properly dispose of unwanted e-medical equipment (third subset).

The third set of variables represents the drivers of proactive environmental initiatives, including the influence of external actors while the fourth and last set of variables attempt to capture the alleged benefits derived from these initiatives.

C. Profile of responding firms

Responding firms include small and medium-sized enterprises and large organizations. They employ in average 156 full-time employees (with a standard deviation of 80,00). All 59 responding firms are highly internationalized and consider that their customers (mainly hospitals) are highly sophisticated and demanding. The average life span of their products is about eleven years. Most firms in our sample (58%) have implanted a TQM program while 39% are certified ISO 9000. Only 3% are certified ISO 14000 (total quality environmental management program).

IV. Results and Discussion

A. Initiatives undertaken by producers to green e-medical equipment

Table 1 displays the mean of the 15 initiatives undertaken by the producers of e-medical equipment (first column) and the relative importance of these initiatives (second column). Overall, one can conclude these initiatives are customer oriented since the first top three initiatives (ranks 1, 2, and 3) affect directly their clients (here healthcare organizations in general and hospitals in particular). These three initiatives, namely *Increase the product durability* (4,58)*, Design product for multiple uses* (4,51) and *Reduce the energy needed to use the product* (4,27), are closely aligned with the concept of extended producer responsibility. From a business perspective, this represents a sound strategy.

Efforts to minimize the waste problems downstream appear to be minimal as the last three priorities (ranks 13,14 and 15) have a direct impact on waste management organizations: *Design the product in order to be easier to recycle* (3, 20), *Establish recycling procedures* (2,74) and *Ensure the presence of recycling infrastructures* (2,69). Collaboration between the

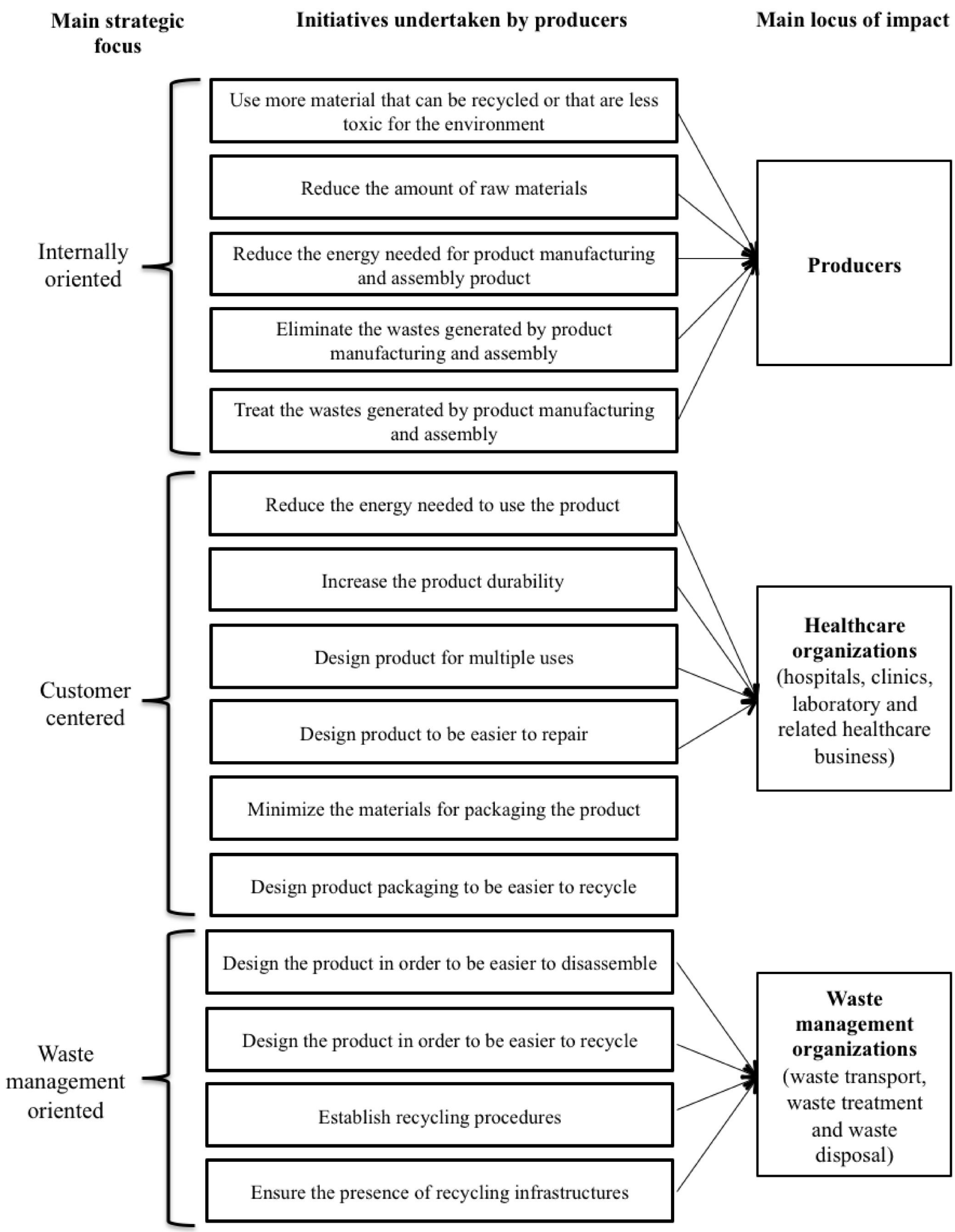

Fig. 2 Initiatives undertaken by producers, main strategic focus and main locus of impact

e-medical equipment producers and waste management organizations seems to be rather weak.

TABLE I
INITIATIVES UNDERTAKEN BY PRODUCERS AND THEIR RELATIVE IMPORTANCE

	Mean[1] (n=59)	Rank
Internally oriented strategies- Initiatives undertaken by producers that have an impact on the producers themselves		
Treat the wastes generated by product manufacturing and assembly	3,21	12
Eliminate the wastes generated by product manufacturing and assembly	3,79	6
Reduce the energy needed for product manufacturing and assembly product	3,59	9
Reduce the amount of raw materials	3,72	8
Use more material that can be recycled or that are less toxic for the environment	3,82	4
Customer oriented strategies- Initiatives undertaken by producers that have an impact on healthcare organizations (including hospitals)		
Design product packaging to be easier to recycle	3,80	5
Minimize the materials for packaging the product	3,65	7
Design product to be easier to repair	3,40	11
Design product for multiple uses	4,51	2
Increase the product durability	4,58	1
Reduce the energy needed to use the product	4,27	3
Waste management oriented strategies- Initiatives undertaken by producers that have an impact on waste management organizations		
Ensure the presence of recycling infrastructures	2,69	15
Establish recycling procedures	2,74	14
Design the product in order to be easier to recycle	3,20	13
Design the product in order to be easier to disassemble	3,50	10

1: Mean based on a Likert scale where 1 = not effort and 7 = considerable efforts

The *Use more material that can be recycled or that are less toxic for the environment* (rank 4) reflects the current regional and national policies restricting the use of hazardous substances and heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame retardants in e-medical equipment. For instance, mercury thermometers are banned in the European Union since 2008 and a similar ban on sphygmomanometers is also being considered. Producers have no choice but to take into account the existing or forthcoming legislation.

The environmental initiatives undertaken by the producers represent a step in the right direction as efforts are mainly directed at "greening" both the design of e- medical equipment (ranks 1, 2, 3, 10 and 13) and the packaging of these products (ranks 5 and 7). These efforts are also cost effective (*Eliminate the wastes generated by product manufacturing* - rank 6, *Reduce the amount of raw materials* - rank 8, and *Reduce the energy needed for product manufacturing* - rank 9) and have a positive impact on the bottom line of these firms.

B. Drivers of the initiatives undertaken by producers to green e-medical equipment

The main driver of proactive environmental initiatives is the influence of customers (Figure 3). This result is congruent with the results presented in Table 1. Market opportunities such as increasing market share, cost reductions opportunities and competitors' products are also strong drivers of environmental efforts. However, current and projected regulations seem to play a moderate role. This later results may be explained by fact that e-medical equipment has an ambiguous status in the environmental legislation and the initial ambitious targets of environmental policies in the European Union, the U.S. and Canada tend to be postponed.

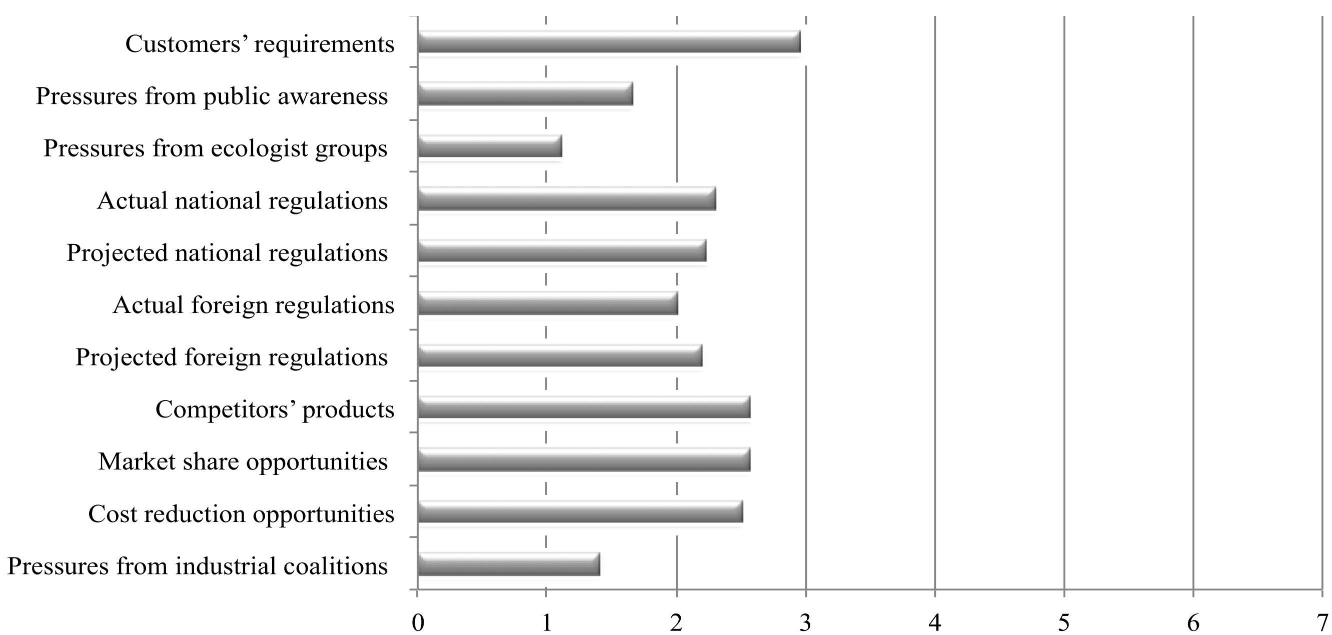

Fig 3. Main drivers of proactive environmental initiatives (Mean based on a Likert scale where 1 = Not influence at all and 7 = considerable influence)

C. Benefits derived from the initiatives undertaken by producers to green e-medical equipment

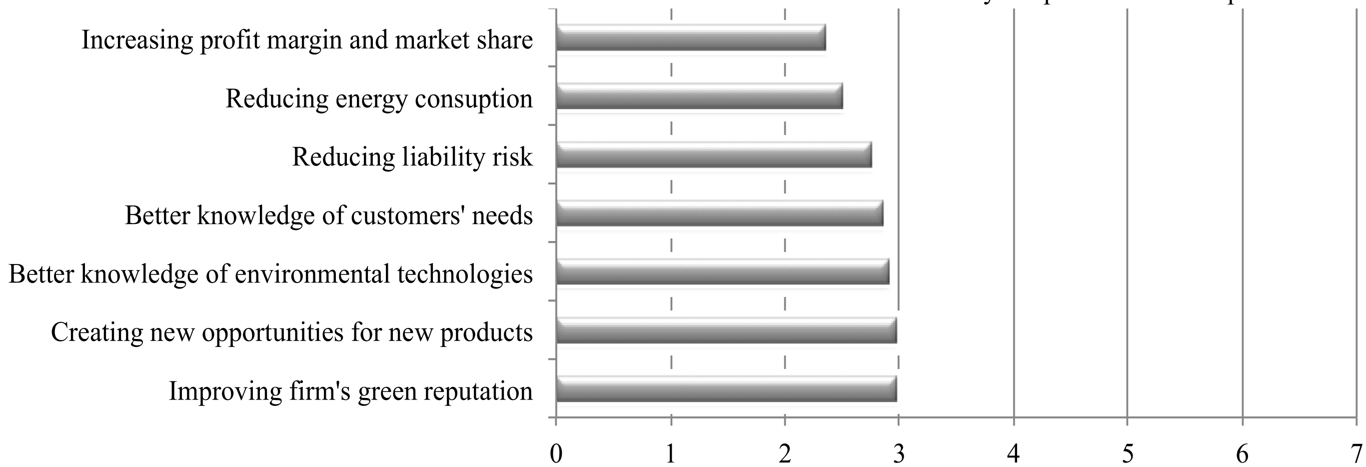

Fig 4. Key benefits derived from proactive environmental initiatives (Mean based on a Likert scale where 1 = No benefits and 7 = considerable benefits)

Benefits from greening e-medical equipment may be wide-ranging as e-medical equipment represents a serious environmental burden at the end of its useful life. In fact, e-medical equipment constitutes an increasingly significant proportion of the e-waste generated worldwide and, like other types of e-waste, represents a danger to the public health and security as discussed previously in section II part C.

Benefits derived from greening e-medical equipment are therefore first and foremost directed towards the society and populations worldwide and fall mainly under the ethical business and corporate social responsibility of the producers. This is closely in line with the most important benefit that producers feel they gain from their environmentally proactive initiatives, namely improving *their firms' reputation* (Figure 4). Second to this rather intangible benefit comes the fact that the environmentally proactive initiatives may *create new opportunities for new products* which is basically a market driven benefit. It is also interesting to note that greening e-medical equipment also allows producers to build environmental and market capabilities *(Better knowledge of environmental technologies* and *better knowledge of customers' needs- respectively* third and fourth ranks in Figure 4). *Reducing the liability risk* (rank 5) is perceived as a more marginal benefit although the compliance with legal standards and the adherence to environmental regulations are increasingly being enforced. Surprisingly, environmental initiatives affect to a lesser extent the bottom line *(Increasing profit margin and market share*- last rank). Overall, the results presented in Figure 4 seem to suggest that the producers of e-medical equipment fail to fully capitalize on their environmental initiatives.

V. Conclusion

Greening the e-medical equipment represents a "healthy" option to minimize the negative impacts of healthcare activities on human health and the environment. The empirical results presented in this paper suggest that the producers of e-medical equipment appear to embrace to a certain extent the concept of extended producer responsibility. Their environmental initiatives are mainly customer driven as they respond to the requirements of healthcare organizations but are still not directed enough towards the end-of-life management of their products. These products are likely to continue to contribute to the e-waste tsunami. The study also demonstrate that the drivers are also customer driven and seem to respond to business imperatives such as increasing market share, reducing costs and offering products that are environmentally friendlier than the competitors. Surprisingly, current and anticipated legislation does not act as a strong driver. Benefits derived from greening e-medical equipment are mostly intangible and so far fail to increase significantly the bottom line. However, as producers of e-medical equipment are building stronger capabilities, they may gain long term and more sustainable competitive advantages

Implications are far reaching. First, the communication and the collaboration from the upstream side (i.e. producers) to the downstream side (i.e. waste management organizations) need to be greatly improved. The end-of-life management of e-medical products requires continuous and specific attention due mainly to the toxicity of some heavy metals and materials. Second, legislation for electronic products in general, especially in the European Union, has been proactive but is too often subjected to debates that lengthen its full application. Targets are revised and exceptions, in particular for e-medical equipment, are made, sending a mixed message to the business community and the general public. Third, increased levels of international collaboration could remove the regional disparities with respect to environmental legislation and policies between continents and countries. Worst, within the U.S and Canada, legislation concerning e-waste differs from state to state and from province to province. The globalized economy and the worldwide burden of e-waste require a more coherent approach to legislation.

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APPENDIX I

THEORETICAL JUSTIFICATION OF THE INITIATIVES UNDERTAKEN BY THE PRODUCERS TO GREEN E-MEDICAL EQUIPMENT

Internally oriented strategies	***Initiatives undertaken by producers that have an impact on the producers themselves***	***Theoretical justification***
	Use more materials that are recycled or less toxic for the environment	[28]; [29]; [30];
	Reduce the amount of raw materials	[31]; [32];
	Reduce the energy needed for product manufacturing and assembly	[31]; [32];
	Eliminate the wastes generated by product manufacturing and assembly	[32]; [33];
	Treat the wastes generated by product manufacturing and assembly	[32]; [33];
	Minimize the wastes generated by product manufacturing and assembly	[32];
	Establish mechanisms to dispose of the wastes generated by product manufacturing and assembly	[32]; [33];
Customer oriented strategies	***Initiatives undertaken by producers that have an impact on healthcare organizations (including hospitals)***	***Theoretical justification***
	Reduce the energy needed to use the product	[31]; [34];
	Increase the product durability	[31]; [35]; [36];
	Design product for multiple uses	[31]; [35]; [36];
	Design product to be easier to repair	[35]; [36]; [37]; [38];
	Minimize the materials for packaging the product	[31]; [39];
	Design product packaging to be easier to recycle	[39];
Waste management oriented strategies	***Initiatives undertaken by producers that have an impact on waste management organizations***	***Theoretical justification***
	Design the product in order to be easier to disassemble	[30];
	Design the product in order to be easier to recycle	[28]; [29]; [30];
	Establish recycling procedures	[28]; [29]; [40];
	Ensure the presence of recycling infrastructures	[28]; [29]; [30]; [40]; [41];
	Establish the mechanisms for disposing the hazardous and infected materials	[28]; [29]; [33]; [42];