A waste lexicon to negotiate extended producer responsibility in free trade agreements

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Abstract

Developing economies largely rely on imported consumer goods from the manufacturing industries of industrialized economies through free-trade agreements.

After consumption, goods end-up in local waste streams and landfilled because of poorly developed waste management systems.

This paper proposes a methodology to extend responsibility to exporting country manufacturers for indirect waste disposal in developing countries through imported goods.

It establishes a functional relationship between the weight and volume of the imported goods and the local municipal solid waste stream derived from their consumption, by adapting the recycling concepts of by-product and co-product to the municipal solid waste stream derived from the household sector.

A lexicon is formalized to conceptualize an extended-producer-responsibility information system operating at the global level between exporting and importing countries. This EPR system i) determines the recyclability, reusability and treatability attributes of imported goods based on their constitutive parts (primary package or product), as well as the material value as per the net value in the global waste market and final destination once consumed, ii) defines specific conditions regarding the goods´ materials value and structural configuration of their constitutive parts for inclusion in Free-Trade Agreement clauses, and iii) checks for the fulfilment of these proposed conditions.

The proposed methodology was validated with a case study on Panama. It was found that 24%(w/w)-34.5%(v/v) of valued materials derived from goods imported in Panama through FTAs could be exported back to the country of origin, 18%(w/w)-2.8%(v/v) could be locally reused, and 58%(w/w)-62.5%(v/v) locally valorized. Only 16%(w/w)-16%(v/v) would have to be landfilled.

Keywords: Extended producer responsibility; free-trade agreement; imported consumer goods; developing economies; landfill waste diversion; decision-support system.

Highlights

- Trade liberalization through free-trade agreements involves indirect pollution
- An extended producer responsibility information system at global level is proposed
- A waste lexicon and decision support system are developed
- The approach is validated with a case study on Panama
- 24% (w/w) of valued materials derived from imported goods could be returned to origin

1. Introduction

In 1986, The Khian Sea ship attempted to deliver a cargo of 15,000 tons of incinerator toxic ash from Philadelphia to the shores of Panama. Just before arrival to destination, the deal was put off by the Panamanian government. For two years the ship roamed the seas in search of a host for its load (Uva and Bloom, 1992). In 1988, The Khian Sea returned home empty, the whereabouts of the cargo were never revealed. Had it not been for the massive closure of US landfills during the early ’80s, the ash might have been disposed of in the Philadelphia landfill.

It was a global waste trade agreement that triggered the travel of The Khian Sea with the offer of 10 million USD to the Panamanian government for importing a total 250,000 tons of ashes ($40/ton) at the expense of the local environment (Uva and Bloom, 1992).

At present, the governments of most developing countries, including Panama, have acquired sufficient environmental consciousness to refuse this kind of deals (Llorach-Massana et al., 2015) with some exceptions (Kollikkathara et al., 2009; Papu-Zamxaka et al., 2010; Demaria, 2010; Hoornweg and Bhada, 2012). However, today's global waste trade encompasses more than the direct export of waste; it also includes less evident processes that go under the name" trade liberalization". Trade liberalization is a way of indirect pollution of developing countries through the import of consumer goods from industrialized economies that eventually will become waste after being consumed and non-deliberately disposed of in the local Municipal Solid Waste Stream (MSWS) of barely established waste management systems (Baldwin, 1993). Waste, either directly imported or generated in-situ from imported goods, is a threat to developing countries.

Today, the world's 20 most industrialized economies manufacture and export 60% of the world goods (UNCTAD, 2018). The rest of the world exports on average 93% less goods per country than these industrialized economies (CIA, 2017). The Free Trade Agreement (FTA) (the most common type of bilateral trade agreement) is a fast-proliferating way for countries to satisfy their needs and achieve their economic goals. By 2007 every country in the world was a member of at least one FTA, most countries being member of several (Menon, 2007). FTAs, signed between industrialized and non-industrialized economies, generally do not include clauses about the Extended Producer Responsibility (EPR) for local waste streams associated with the exported goods (ECLAC, 2017).

After imported goods are consumed, they become 'consumed goods' and in most developing countries the materials making up their constitutive parts are indiscriminately mixed up in the local municipal solid waste stream because, more often than not, waste source-separation is poorly developed or implemented. In the household sector of these countries, the solid waste generated is collected and transported commingled as bulk waste and disposed of in landfills. Although landfills remain the most common method for waste disposal worldwide and are considered a reliable and low-cost alternative to final solid waste disposal (Powrie and White, 2004; Zacharof and Butler, 2004; Caprile and Ripa, 2014), there is little awareness that not all consumed goods have to end up as waste (JICA, 2005). Indeed, diverting waste from landfills through material and resource recovery is an important goal of many environmental policies worldwide (EEA, 2009; Ripa et al., 2017; UNEP, 2009).

Materials recovery, by reusing consumed goods as second-hand goods before being disposed of or by recycling in the manufacturing industry, as well as energy recovery, by valorizing waste materials in treatment plants as energetic resource before landfilling, requires integral and robust waste management strategies, like the ‘zero-waste concept’ (Islam and Jashimuddin, 2017). Many industrialized economies have locally implemented EPR systems¡ to make the manufacturer of the product responsible for the entire life-cycle of the product and especially for the take-back, recycling and final disposal (Lindhqvist, 2000a). Good examples are PRO Europe´s Green Dot®, NAFTA region´s Green Dot North America and UK´s VALPAK (Song et al., 2015). However, in developing economies, material and energy recovery of MSWSs by reusing or valorizing, are only slowly implemented. For recycling to be implemented through EPR systems, a minimum level of MSWS management and consumer´s contribution to waste source-separation would have to be accomplished first (Lindhqvist, 2000b). Local recycling of MSWS materials is still an unreliable option because the manufacturing industry is only incipient in these economies. Waste export thus remains the main alternative to divert waste from landfills and relief the local waste management system (Troschinetz and Mihelcic, 2009).

Waste exporting requires the assignment of value to waste materials as per the global waste market (**Figure 1**). In the global waste market, non-tradable materials are unvalued materials while tradable materials are valued materials (Kollikkathara et al., 2009). The global waste market defines the value of materials according to their technical and economic viability of recycling. Some waste materials are technically recyclable in the global waste market, but poor cost-effectiveness of available recycling methods results in a low net waste value, thus classifying them as unvalued materials and making local management through reuse, valorization or landfilling a more suitable option (Soo et al., 2017). For instance, expanded polystyrene, used for food-service, is a high-volume, low-weight material composed mainly of air with such high transport and recycling costs that it is considered ‘economically non-recyclable’ in the global market (NYCDOS, 2017). Also for wooden crates, locally used to deliver fruits and vegetables, local reuse or landfilling is preferred over global recycling (Ng et al., 2014). Unvalued materials, including the organic fraction, could be valorized in different ways but the global market net waste value does not apply to valued materials segregated from unvalued materials (**Figure 1**) (García et al., 2012; Ali and Courtenay, 2014; Lee et al., 2014).

The relative material composition of goods is measurable from the manufacturing stage to the point of consumption while the goods´ primary package (and product itself) is still in place. In the post-consumption stage, the material composition changes depending on country-specific variables, such as resource consumption habits, waste generation behaviors, waste deposition patterns (Kofoworola and Gheewala, 2009), local weather conditions and street animal behavior (Tchobanoglous, 2009). Within the MSWS, the constitutive parts of consumed goods are subject to weight and volume changes in variable degrees. For instance, volume changes of goods´ primary packages are less likely to happen than weight changes of both, organic product of the packaged goods and unpackaged products. The material composition of consumed goods in MSWSs can still be estimated in absolute quantities using waste classification traditional systems that classify waste by composition of material groups (DEQ, 2004; IPCC, 2000) but these systems are not useful to understand management options of consumed goods´ materials before consumption. Note that there is little awareness that volume measurements are complementary to weight measurements to accurately assess the recycling viability of the MSWS materials as valued material by their attributes before transformation into consumed goods (Bing et al., 2014).

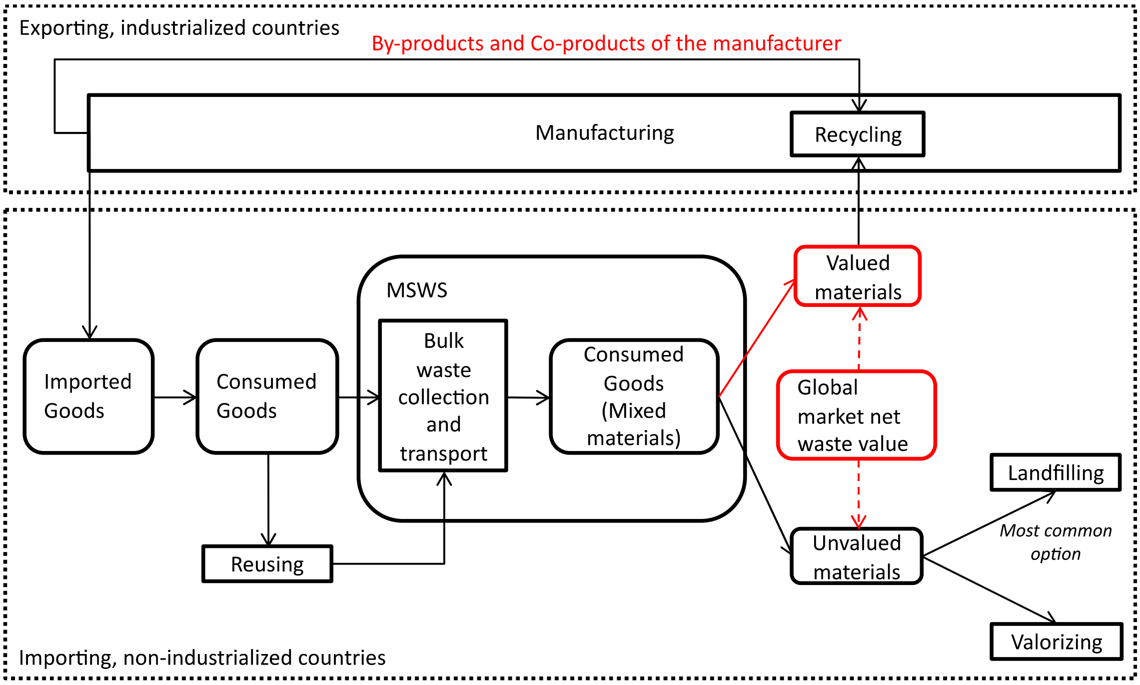


Figure 1. *Import of goods, municipal solid waste generation, and recycling.*

Recognition of the nexus between the quantity, (material) composition and proportions of the constitutive parts of imported goods (goods´ primary packages, primary packaged goods and unpackaged products) before and after ending up in the local (mixed) municipal solid waste stream (Savino et al., 2018) is a necessary step for developing economies to determine the recyclability potential of the waste materials derived from imported goods through FTAs and label them valued or unvalued materials according to the net waste value on the global market. Simply accounting for the quantity, composition and relative proportions of imported goods does not, and cannot accurately reflect the quantity, composition and relative proportions of the consumed goods´ mixed materials in the local MSWS so as to assign responsibility for the reception of valued materials derived from the economic activity. Indeed, there is a need for the formalization of a new lexicon for a functional waste classification system allowing to conceptualize the definitions of an EPR-like information system at the global level, thus recognizing the complex relation between industrialized exporting countries and developing importing countries. Such lexicon would facilitate the assignment of a globally extended responsibility to industrialized economies for the waste flows they produce in developing countries and to assess the potential of local MSWSs for local management as unvalued materials or recycling in the global market as valued materials.

This paper aims to open a debate about how to extend responsibility to industrialized economies for indirect waste disposal in developing countries through imported goods. It proposes a conceptual approach for an EPR information system at the global level that establishes a functional relationship between the weight and volume of the imported goods and the local municipal solid waste stream derived from their consumption. To this purpose, in the following section, a waste lexicon is defined. The recycling concepts of by-products and co-products of the manufacturer are adapted to imported goods and the corresponding waste generated to create a lexicon based on the constitutive parts, material value and final destination of the consumed goods. Conditions on the goods´ material value and structural configuration that should be declared in FTAs and fulfilled are proposed. In section 3, the proposed methodology is validated with a case study on Panama, using data on the quantity and composition of imported consumer goods through FTAs, and data on the quantity and composition of the consumed goods´ materials in the municipal solid waste stream. The case study examines the extent to which: i) consumed imported goods in the household sector could be reused before being inputted into the MSWS, ii) the materials of the MSWS are valued materials or unvalued materials as per their global market net waste value, iii) valued materials could be recycled back to industrialized economies, and iv) unvalued materials could be valorized or landfilled. Section 4 discusses the results and concludes.

2. Materials and methods

2.1 Lexicon for a consumed good material classification system

A “good” is defined here as a final product that may or may not be packaged for final consumption by consumers satisfying their current wants or needs rather than used in the production of another good. As for packaged goods, there are basically three major packaging layers that protect the goods during the stages of the trade process: (i) a transport packaging layer for manufacturing/transport, such as pallets, (ii) a secondary packaging layer for distribution/display, such as cases, and (iii) a primary packaging layer for acquisition/consumption (inner packs). The constitutive parts of goods are the goods´ primary package and the product itself which may be product of the packaged good or unpackaged product; the latter is a good acquired without primary packaging (Hansen et al., 2012; Robertson and Hamza, 2016).

Product manufacturing entails the generation of co-products of the manufacturer and by-products of the manufacturer. Both are secondary products linked to the manufacturing of goods; while co-products are planned for by the manufacturer, by-products are not. Co-products are normally tradable without any additional treatment, while by-products usually serve as additives or raw material replacement in the manufacturing of other products or even the same manufacturing process from which it was created (**Figures 1 and 2**) (Ali et al., 2009; Sandin et al., 2015).

By adapting the recycling concepts of by-products and co-products of the manufacturer to imported goods, a novel lexicon is proposed in **Figure 2** to define (i) consumed goods as a function of their final destination (i.e., recycling, reusing, valorizing, landfilling), and (ii) constitutive parts (i.e., goods´ primary package, product of the packaged good and unpackaged product) as a function of their net waste value in the global market (i.e., valued materials, unvalued materials).

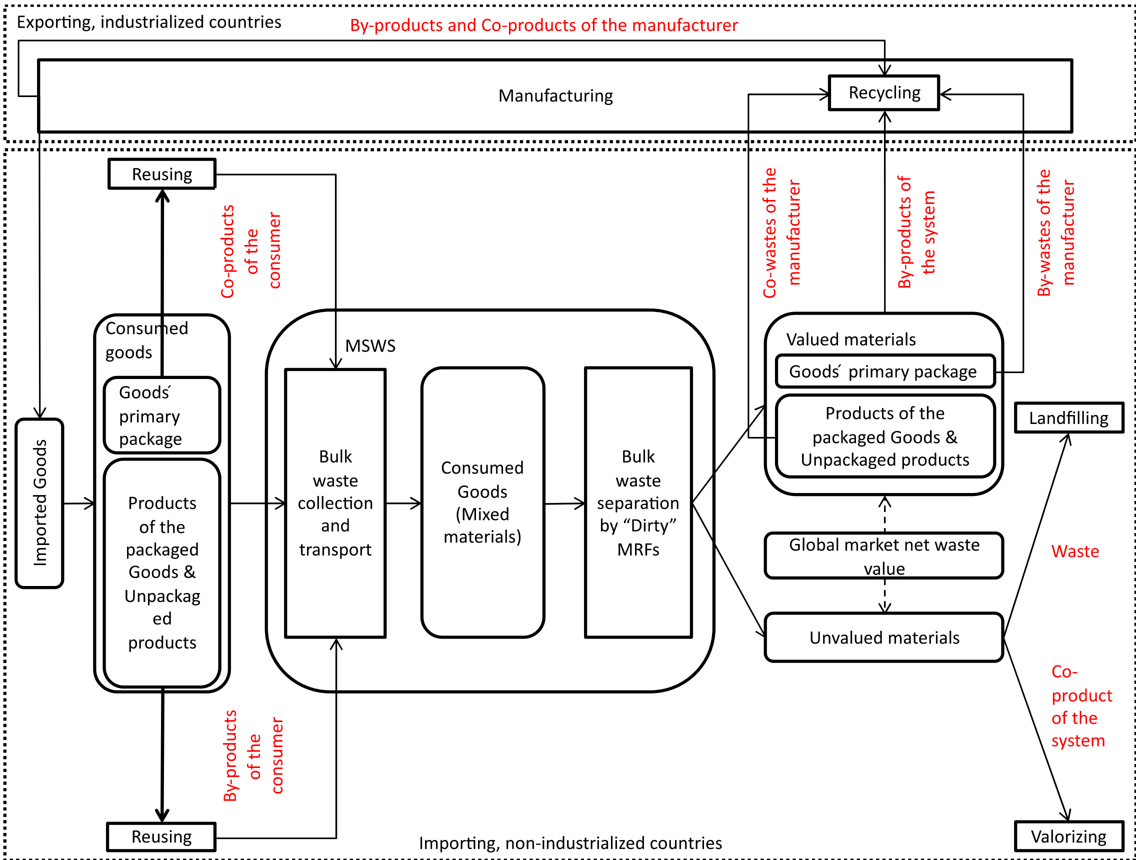


Figure 2. *An expanded waste lexicon for imported goods.*

2.1.2. Reusability: By-product and co-product of the consumer

As shown in Figure 2, before being inputted to the local MSWS, consumed goods´ parts can become either 'by-product of the consumer' or 'co-product of the consumer' through reuse. After goods are acquired, products (either product of the packaged good or unpackaged product) are used until they lose value for the consumer who acquired them. The concept of by-product of the consumer is analogous to that of by-product of the manufacturer: products that lost their value for the first consumer in an unplanned manner become useful for other consumers (second-hand products). This is the case for products like clothes, shoes, books, electronic products, toys, tires, etc. The exchange of the imported products among consumers is a closed deal and not associated with the terms of imported goods through FTAs. Reuse of a product of the packaged good or unpackaged product by the original (same) consumer is not considered here as reusing but using.

In a similar way, the concept of co-product of the consumer is the analogue of co-product of the manufacturer: the imported goods´ primary packages may find a new use for the consumer who acquired the packaged good in a planned and foreseeable manner thus deciding not to dispose of it. Examples are shoe boxes, mayonnaise jars, jewelry cases, etc.

Goods´ primary packages that are not (meant to be) reused by the first consumer who acquired the good (or other consumers) as well as products of packaged goods and unpackaged goods that can no longer be (re)used because they reached their end of lifetime are inputted into the MSWS.

The reuse of consumed goods will depend upon the consumer who acquired the goods, and will be influenced by local factors such as culture, education and environmental consciousness. In some cases, waste collection workers may act as secondary consumers of consumed goods disposed of by consumers.

2.1.3. Implementation of ‘dirty’ material recovery facilities

To open the possibility of returning valued materials to industrialized economies, a segregating/packaging/exporting process is considered where separation of mixed consumed goods´ materials in the MSWS by their constitutive parts and material value is performed by ‘dirty’ Material Recovery Facilities (MRFs) accepting commingled waste. ‘Dirty’ MRFs are expected to segregate unvalued materials, including most of the organic fraction, from dry recyclables materials (valued materials) that can be packaged and exported back to industrialized economies (Modak et al., 2015).

Traditional waste classification systems (DEQ, 2004; IPCC, 2000) can be used to identify material composition once the consumed goods´ parts are recovered from the MSWS. Material value in the global waste market can then be determined as per their global market net waste value, where valued materials are recyclable and unvalued materials are not (Martínez Urreaga et al., 2015).

2.1.4. Treatability: Co-product of the system and “waste” concepts

According to (Ali and Courtenay, 2014), an average of 92% of the MSWS inputted to ‘dirty’ MRFs could be recycled, 6% valorized and the remaining 2% landfilled. Unvalued materials of the MSWS with the potential to be valorized as energy, organic amendment, RFD, syngas, etc., are defined as ‘co-product of the system’ (**Figure 2**), because in a certain way they are being “reused” after proper treatment. Unvalued materials that cannot be recovered are defined as ‘waste’.

The handling of unvalued materials as co-product of the system or waste is a responsibility of the local waste management system. If this system is poorly developed then ‘co-product of the system’ will end up with ‘waste’ in landfills and produce environmental pressure, thus following the business-as-usual case (Schubert, 2014).

2.1.5. Recyclability: By-product of the system, co-waste of the manufacturer and by-waste of the manufacturer concepts

Valued materials derived from the output of consumed goods of the MSWS are considered ‘by-product of the system’ (**Figure 2**). They may need further processing through recycling in the manufacturing industry of the industrialized economy that produced the goods. After by-products of the system are exported back to the country of origin, they can either be used directly in the receiving manufacturing industry as co-products of the manufacturer or a second pre-treatment by a specific-purpose material recovery facility could be performed within their recycling process to increase the quality for use as by-products of the manufacturer.

The concepts ‘co-waste of the manufacturer’ and ‘by-waste of the manufacturer’ are introduced to define the valued-material waste returned to the manufacturer derived from, respectively, the product of the packaged good/unpackaged product and the primary package part of the consumed goods. The aggregate of co-waste of the manufacturer and by-waste of the manufacturer constitutes the ‘by-product of the system’.

The acknowledgement of the ‘by-product of the system’ would allow the importing country to inform the manufacturers in industrialized economies about the proportion of the imported goods being returned through recycling. The extent to which consumed goods become by-product of the system could determine the tradability level of goods before being included in FTAs. Valued materials recycled through this process would relief the local waste management system through landfill waste diversion.

2.2. Decision support system

The flow diagram in **Figure 3** provides a decision support system for the implementation of globally extended producer responsibility in trade agreements (FTA clauses) related to the import of consumer goods in developing countries. It establishes relationships among the defined lexicon (shown in blue) through proposed actions (shown in green) taken according to certain criteria/conditions (shown in yellow).

The information on imported goods required from the manufacturer in the exporting country includes, besides total quantity and type of product: i) constitutive parts (goods´ primary package and product of the packaged good or unpackaged product), ii) type, proportion and value of materials, including the current global market net waste value and its forecasted variation within a determined period. This information will allow the importing party to survey for valued materials in the MSWS, using the proposed lexicon, and return them to the manufacturer as per declared.

As shown in Figure 3, manufacturers do not have to guarantee that each valued material declared will be tradable as per its economic viability but recyclable as per its technical viability. This is relevant as the quality of valued material returned to industrialized economies will depend on the local separation process. It is the responsibility of the importing party to improve the efficiency of the dirty MRF so as to obtain the highest quality of valued materials.

Each good proposed for importing should be checked by both FTA parties for the fulfillment of the following conditions:

1. to encourage waste diversion from landfills, volume and weight of valued materials should be larger than volume and weight of unvalued materials as per the global market net waste value (i.e., in Fig. 3: $V_{VM} > V_{UM}$ and $W_{VM} > W_{UM}$, respectively), and
2. to discourage the consumption of over-packaged goods, the volume of imported goods that are valued materials should not be more than 3 times the volume of the products contained (product of the packaged good plus unpackaged product) ($V_{VM\ GPP+PPG+UP} / V_{VM\ PPG+UP} \leq 3$) (Wang et al., 2018). Unpackaged product is added to the condition to incentivize the import of goods without packaging. Also, the weight of the product parts of imported goods (products of the packaged goods plus unpackaged products) that are valued materials should be larger or equal to the weight of the imported goods´ primary packages (in Fig 3: $W_{PPG+UP} \geq W_{GPP}$).

If any of these conditions are not met, proper justification should be given by industrialized economies before goods can be traded with non-industrialized economies through FTAs. Justification could be complimented with determined tariffs to industrialized economies to support diversion of unvalued materials from landfills and valorization instead.

In addition, the importing economies could locally check the fulfillment of these conditions by examining the following relationships among the MSWS outputs according to the defined lexicon: (i) volume and weight of 'by-product of the system' should be larger than volume and weight of 'waste and co-product of the system' ($V_{BPS} > [V_{Waste} + V_{CPS}]$ and $W_{BPS} > [W_{Waste} + W_{CPS}]$) and (ii) the volume of 'by-product of the system' should not be more than 3 times the volume of 'co-waste of the manufacturer' ($V_{BPS} / V_{CWM} \leq 3$) and weight of 'co-waste of the manufacturer' should be larger or equal to weight of 'by-waste of the manufacturer' ($W_{CWM} \geq W_{BWM}$). The use of the defined lexicon (co-waste of the manufacturer, by-product of the system, by-waste of the manufacturer, co-product of the consumer, by-product of the consumer, and co-product of the system) would be internal to the importing country, the industrialized exporting countries would only have to manage the concepts of valued and unvalued materials, goods´ primary package, product of the packaged good and unpackaged product for declaration purposes.

This overall assessment will also include goods of the MSWS that are not derived from FTAs, so relationships among the MSWS outputs should be checked according to the proposed lexicon before and after the FTA is implemented to assess the effects on the whole MSWS by comparing yields through time. Valued materials for return to the country of origin are allocated from the total output valued materials derived from the MSWS separation process according to the declared features of the imported goods –i.e. quantity, type and proportion of materials and functional parts as imported goods (goods´ primary package, product of the packaged good and unpackaged product).

As goods can also be reused as 'co-product of the consumer' or 'by-product of the consumer', qualitative mechanisms acknowledging reuse practices in society could be implemented to monitor the change in overall reusing rates in reference to the input of imported goods.

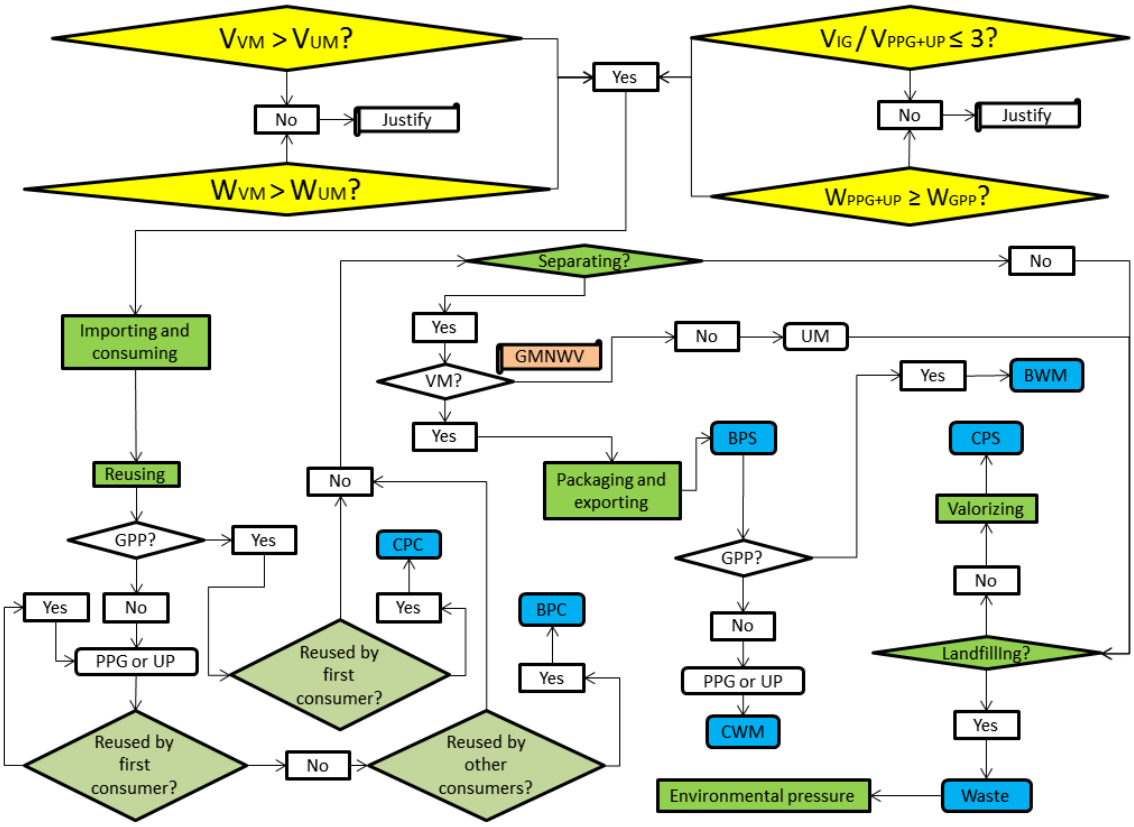


Figure 3*. Flow diagram to establish relationships among the defined lexicon (blue) through actions (green) taken according to criterions (yellow). Abbreviations: V: volume; W: weight; VM: values materials; UM: unvalued materials; IG: imported Goods; PPG: products of the packaged Goods; UP: unpackaged products; GPP: Goods´ primary package; BPC: by-products of the consumer; CPC: co-products of the consumer; BPS: by-products of the system; CPS: co-products of the system; BWM: by-wastes of the manufacturer; CWM: co-wastes of the manufacturer; GMNWV: global market net waste value.*

3. Case study

3.1. Case study selection

Panama accounts for 5% of the regional good imports in Latin America; it is ranked 6 out of the 26 Latin-American countries with 1.5% more imports than the average (SICE, 2018). With the highest GDP per capita of the region together with Chile (The World Bank, 2017) and liberal consumption habits acquired from the political and social influence of the USA, Panama is a consumer per excellence (Tagle, 1988). What makes the country particularly attractive for FTA negotiations with industrialized economies is its strategic position: the “hub of the Americas” (Muñoz and Rivera, 2010); Panama is projected as a relative interesting re-exporting market for industrialized economies (UNCTAD, 2017).. Since 2002, Panama has signed around 14 FTAs, 6 from which has been signed with industrialized economies (SICE, 2018) (**Figure 4**).

Currently, China and Panama are negotiating the second round of their FTA (La Prensa, 2018). The FTAs main aim is to increase the exchange of products and services, mostly from the most (China) to the least industrialized economy (Panama). Among the negotiated chapters reported thus far (MIRE, 2018), there is none including environmental provisions (Colyer, 2013) concerning any degree of responsibility for imported goods contribution to the local MSWS once consumed. Within the context of this FTA, the creation of the first Digital Free Trade Zone of the Americas in Panama was recently announced to function as a gateway for Chinese goods to reach Latin American economies in a more effective way through e-commerce and re-exporting (La Prensa, 2019). However, the experience with Panama’s Free Trade Zone of Colón, the largest in the Americas and the second-largest in the world after Hong Kong, has shown that consumer goods will be nationalized as well (Blais et al., 2010).

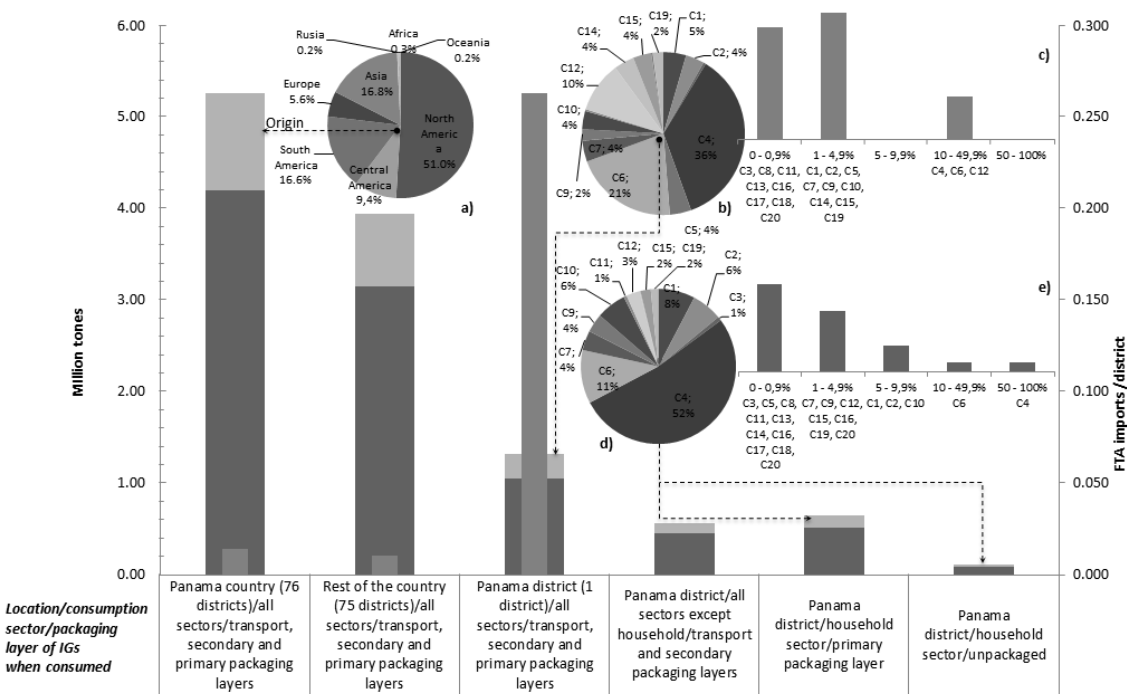
3.2. Import of consumer goods in Panama through FTAs and consumption of imported goods

Figure 4 shows Panama´s overall situation of imported consumer goods in 2016. Imported goods through FTAs with industrialized economies accounted for 20% of the total national imports (INEC, 2018), representing 1.05 million tons (Mt) consumed by the 76 districts that make up the country (**Figure 4,** 1st column). There are 20 differentiated types of imported goods (**Table A1, appendix section**) mainly brought in from North America (51%), South America (17%), and Asia (17%) (**Figure 4-a)**. The Panama district (capital) consumes 25% (0.26 Mt) of the total (national level) goods imported through FTAs; 95% more than the average consumption per district (**Figure 4-**2^{nd} and 3^{rd} columns).

With proportions over 10%, imported consumer goods of types C4, C6 and C12 together account for more than 65% of the weight of all imported types of consumer goods in the capital district (**Figure 4-b**). Once consumed, their contribution in quantity (w/w) to the MSWS is higher than the rest of the imported goods, which proportions (w/w) are lower, however the latter are richer in variety of materials because of their diversity (**Figure 4-c**). From the total imported goods being consumed in the Panama district, 43% (0.11 Mt) is not traded with primary packaging layer or unpackaged through traditional retailing to the end consumer, but with transport/secondary packaging layers through other trade ways (**Figure 4-**$\mathbf{4^{th}}$ **column**) (INEC, 2018). The primary packages of these imported goods are easier to recover because they are not commingled with organic waste in the MSWS from households; they are finally consumed in specific activities of the commercial sector (Modak et al., 2015).

Around 57% of consumer goods imported through FTAs are consumed in the Panama district household´s sector and are retailed with primary packaging layer (product of the packaged goods + goods´ primary package = 0.13 Mt) or unpackaged (0.02 Mt) (**Figure 4,** 5^{th} and 6^{th} columns). When accounting only for this stream of imported goods, the relative contribution (w/w) of the types of goods changes (**Figure 4-d**), with C4 becoming most abundant (52%) and other types of goods becoming more prominent (**Figure 4-e**). This is also reflected in the package types ending up commingled in the MSWS, which is disposed of in the local landfill (**Figure 4-d**).

The density conversion factor as per the EWC code was used to estimate the volume of imported goods from their weight according to the waste type description that best suits each imported good (SEPA, 2015). The total volume of imported goods is around 470 km^3, of which 48% is goods' primary package and 52% is product of the packaged good and unpackaged product. Note that primary packaging accounts on average for 35% of the packaged goods weight but up to 3 times their volume (Wang et al., 2018).



Location/consumption sector/packaging layer of IGs when consumed	Panama country (76 districts)/all sectors/transport, secondary and primary packaging layers	Rest of the country (75 districts)/all sectors/transport, secondary and primary packaging layers	Panama district (1 district)/all sectors/transport, secondary and primary packaging layers	Panama district/all sectors except household/transport and secondary packaging layers	Panama district/household sector/primary packaging layer	Panama district/household sector/unpackaged
FTA imports	1.05	0.79	0.26	0.11	0.13	0.02
Other imports	4.20	3.15	1.05	0.45	0.51	0.08
FTA imports/district	0.014	0.011	0.26			

Figure 4. *Imported goods to Panama in 2016. Graph a: Origin of goods imported to Panama through FTAs (INEC, 2018). Graph b: Proportions of consumed goods´ types imported through FTAs and consumed in the Panama district with transport, secondary and primary packaging layers (w/w). Graph c: Quantities of consumed goods types by their proportion thresholds. Graph d: Redistributed proportions of consumed goods´ types imported through FTAs and consumed with primary packaging layer in the household sector of the Panama district (w/w) and average % per volume. Graph e: Quantities of consumed goods´ types consumed with primary packaging layer in the household sector by their proportion thresholds. Percentages*

smaller than 1% are not shown. IG refers to Imported Goods. Classification codes of types of goods are explained in Appendix Table A1.

3.3. MSWSs to Panama district´s landfill

In 2016, the capital district landfill (Cerro Patacón) had accumulated more than 12 million m^3 of waste during 31 years of operation (AAUD, 2016). It was estimated that the landfill received of total of 2500 t of waste/d (0.913 Mt/y) from different sources; 89% is MSWS generated in households and commerce of the Panama district and its dormitory district, San Miguelito (**Figure A1, appendix section**).

A large part of commercial waste is generated clean and dry directly from commerce (120 t/d), thus allowing partial waste diversion from Cerro Patacón (37%) by the segregation/recovery activities of waste pickers in the landfill who trade the separated materials in-situ with the middleman. The middleman trades it with few wastes materials packaging/exporting companies that place it in the global waste market to the highest bidder as per the current global waste market net value at the moment of the trade. Waste recovered by waste pickers represents not more than 0.2% of all waste disposed of in Cerro Patacón, more than 99% is disposed of mixed without any halfway recyclable material segregation or recovery process (AAUD, 2016).

To account for the MSWS derived from the consumption of imported goods through FTAs in the household sector of the Panama district, only the proportional part of imported goods (20%) that ends up in the MSWS generated in the household sector of the capital district of Panama (336 t/d) is considered, that is, 14% of the total MSWS.

A total of 56 waste fractions in the MSWS from the household sector of the Panama district were characterized in 2016 by the local waste management authority (AAUD, 2016). Waste fractions were reduced to 29 as per their materials´ description (**Table A3, appendix section)** by aggregating them according to i) their structural and functional properties, ii) their tradability as by-product of the system and iii) the environmental pressure exerted when landfilled untreated.

Each fraction of the MSWS was categorized as per waste classification traditional systems assigning definitions to MSWS materials by their structural properties depending on their final destination (**Table A4, appendix section**). For instance, when the goal is to ensure the stability of waste bodies in landfills by the evaluation of waste mechanical properties, Dixon and Langer (2006) mention existing classifications systems based on: i) material groups by composition, size and dimension; ii) waste type by density, shear parameters, liquid/plastic limit, permeability; iii) organic/inorganic materials by degradability degree and shape, degradable/inert/deformable materials by strength, deformability and degradability, and on the distinction between soil- like and non-soil-like (i.e. fibrous) appearance. Zhou et al., (2014) classified municipal solid waste by their thermochemical properties based on proximate and ultimate analysis, heating value and statistical methods such as analysis of variance and cluster analysis. Classification as per their function as constitutive parts of goods (goods´ primary package, product of the packaged good, unpackaged product) and material value (valued and unvalued material) is also presented (**Table A3, appendix section)**.

Proportions in weight (w/w) and volume (v/v) of MSWS fractions of the household sector are shown in **Figure A2 of the appendix section***. Eighteen out of twenty-nine fractions (D12 – D29) are wet fractions, usually derived from product of the packaged goods and unpackaged products, that sum up to 60% (w/w) of the MSWS with an average per fraction of 3% (**Figure A2-a**). The density conversion factor as per the EWC code was used to estimate the volume of MSWS fractions from their weight values (SEPA, 2015) (**Figure A2-b**). Eleven out of twenty-nine fractions (D1 to D11) are light, voluminous and dry container fractions, usually corresponding to goods´ primary packages, that sum up to 50% (v/v) of the MSWS with an average per fraction of 4%. As is typical in developing countries, MSWS fractions of the household sector like D5, D10, D15, D16, D17, D18, D19 and D21 are predominant over other fractions in both weight and volume (Troschinetz and Mihelcic, 2009; Thanh et al., 2010; Dinesh et al., 2018).

The volume of the MSWS is around 457 km^3. Around 40% (w/w) and 49% (v/v) of the MSWS was found to be goods´ primary package, 28% (w/w) and 32% (v/v) to be product of the packaged good, and 33% (w/w) and 19% (v/v) to be unpackaged product. To allocate goods´ primary package from product of the packaged good in imported goods, the identified goods´ primary package fraction of the MSWS (40%) was used, which input as consumed goods and output in the MSWS is assumed to be equivalent. The same was assumed for unpackaged products since their weight proportion within imported goods is kept from imported goods to consumed Goods and to the MSWS.

Figure 5 shows the current allocation of the MSWS disposed of in Cerro Patacón as the final destination (123 kt) and imported goods consumed, collected and transported from the household sector of the Panama district (150 kt). Consumed goods not entering the MSWS (27 kt) could be reused, disposed of through underground dumping or other final destination method. Here it is assumed to be completely reused either by: i) other consumers, or by ii) waste collection workers who conveniently segregate valued materials from the MSWS for underground trading before ending collection routes; both proportions are undetermined (INECO, 2017).

The information shown in **Figure 5** on the imported goods input/MSWS output situation does not yet permit the definition and implementation of an EPR mechanism at the global level to account for the MSWSs locally generated from the imported goods. The implementation of dirty MRF facilities in the importing country is a prerequisite for the system to work.

Before entering the dirty MRF recovery process, around 45% (w/w) (35% goods´ primary package, 10% product of the packaged good plus unpackaged product) and 55% (v/v) (44% goods´ primary package, 11% product of the packaged good plus unpackaged product) of the materials in the MSWS is defined as valued materials (**Table A3, appendix section**). After the dirty MRF process, it is assumed that 29% (w/w) and 36% (v/v) could be recovered (CalRecovery, 2006); 65% of the total valued materials in the MSWS. Around 23% is goods´ primary package, 5.9% is product of the packaged good and 0.2% is unpackaged product (w/w), and 28.4% is goods´ primary package, 7% is product of the packaged good and 0.2% is UP (v/v). From the unvalued material, around 75% is assumed to be valorized and 25% landfilled (Ali and Courtenay, 2014).

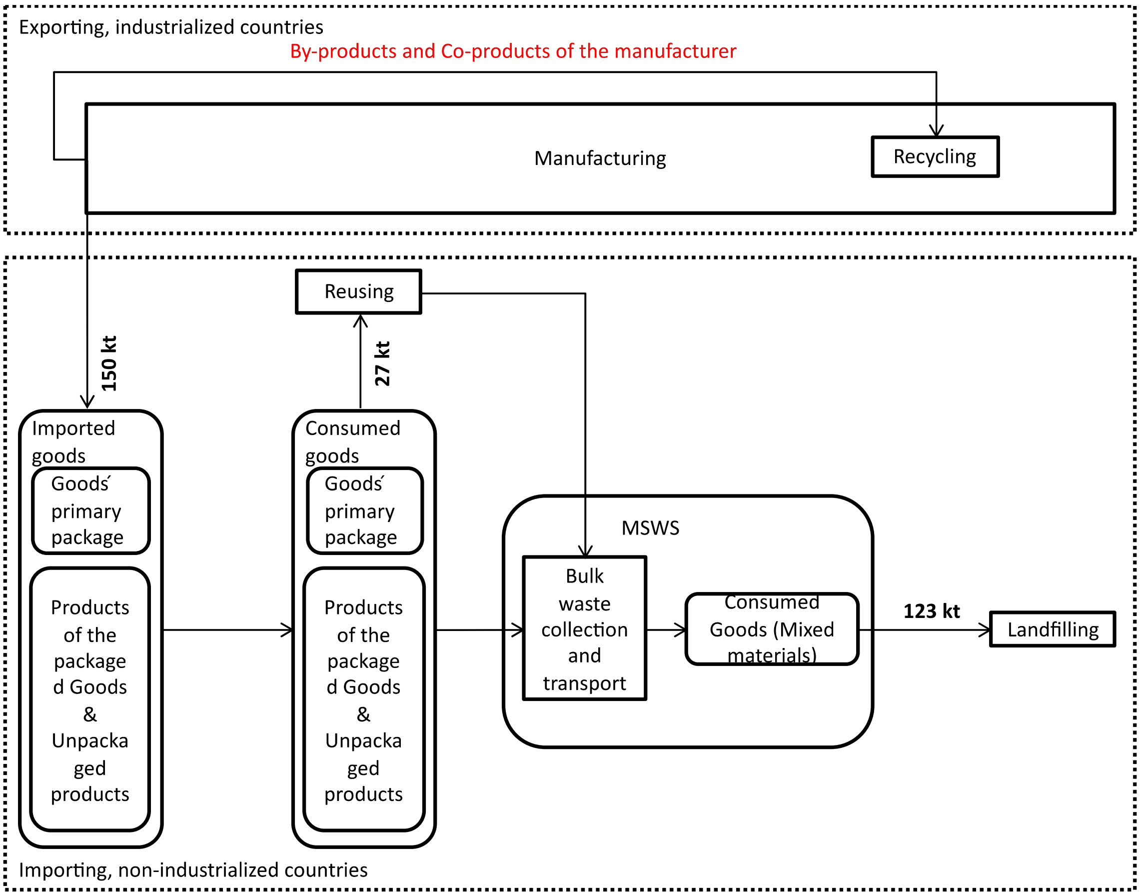


Figure 5. *Current input/output situation of the MSWS disposed of in Cerro Patacón and imported goods consumed, collected and transported from the household sector of the Panama district.*

4. Discussion and conclusions

Using the proposed methodological approach, material flows from imported goods to the MSWS as per the defined lexicon in terms of weight and volume were allocated for the Panama case (**Figure 6**). Overall results for the fulfilment of the proposed conditions for imported goods are also shown (**Table 1**).

Approximately 24% (w/w) / 34.5% (v/v) of imported goods could be exported back as by-product of the system to the industrialized economies through the FTAs with Panama; 5.3% (w/w) / 9.8% (v/v) as by-waste of the manufacturer, and 18.7% (w/w) / 24.7% (v/v) as co-waste of the manufacturer. Hence, the amount of MSWS disposed of as waste in landfills could be significantly reduced in Panama through the inclusion of extended producer responsibility in FTA clauses. Waste backhauling would represent an effective way for the goods´ exporting entity to save on logistics costs emerging from the implementation of the proposed methodology, as ships carrying goods to the importing country could load and carry back waste to the source of origin (Kellenberg, 2010).

Around 82% (w/w) / 97.2% (v/v) of imported goods in Panama is inputted to the MSWS; around 10.7% (w/w) / 2.1% (v/v) is supposedly reused as by-product of the consumer and 7.3% (w/w) / 0.7% (v/v) as co-product of the consumer. Appropriate local mechanisms to monitor the quantity and quality of reused consumed goods (as by-product of the consumer and co-product of the consumer) could improve the effectiveness of awareness campaigns and increase the reuse rate so as to reduce the input to the MSWS.

Around 58% (w/w) / 62.5% (v/v) could be valorized as co-product of the system, so only 16% (w/w) / 16% (v/v) would have to be disposed of as waste in the landfill (Cerro Patacón). It is evident that the implementation of local ´dirty´ MRFs is key to the diverting of >50% of the MSWSs from landfills through the proposed approach. This technology could be recommended as a clause of FTAs with the exporting industrialized economy assuming (partial) responsibility for design, implementation and funding of the facility(ies).

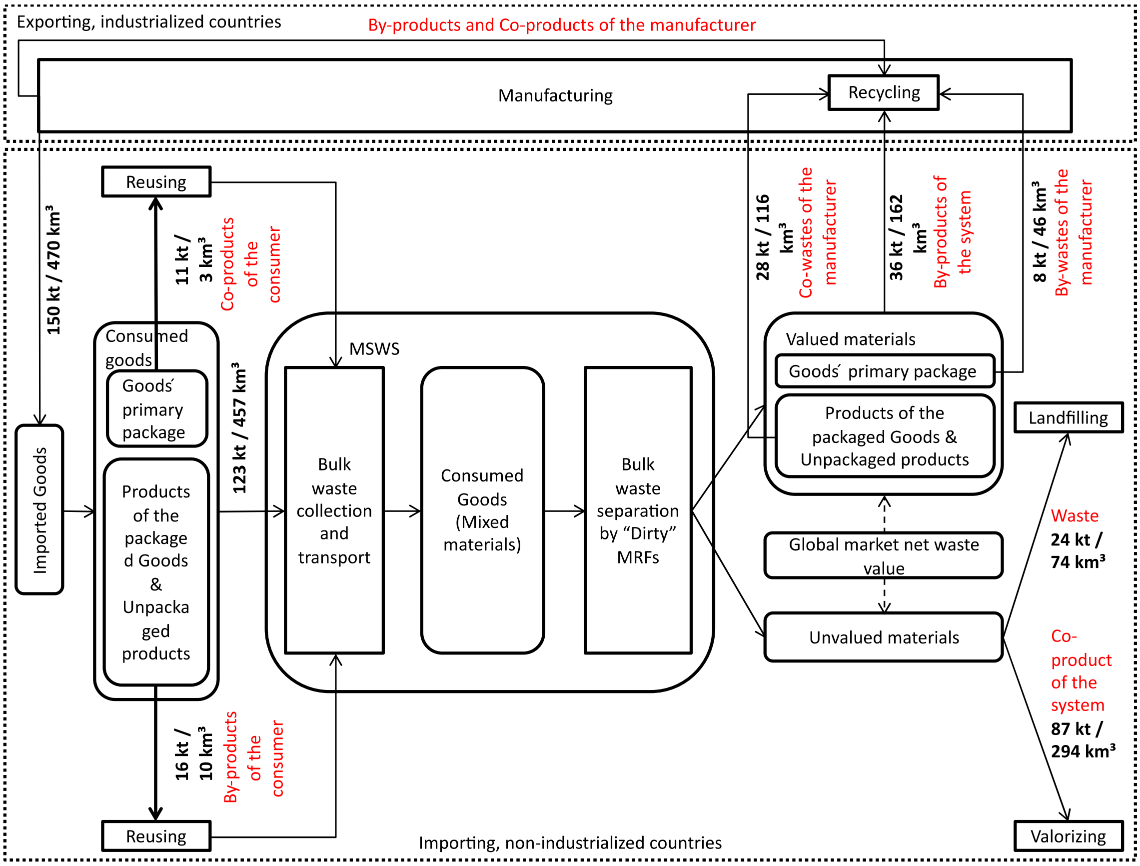


Figure 6. *Allocated material flows from imported goods to the MSWS as per the defined lexicon in terms of weight and volume.*

The aggregate of goods collectively imported by Panama through its FTAs with industrialized economies does not fulfil the materials´ value conditions, neither in terms of weight nor volume. On the other hand, the structural configuration conditions are met both in terms of weight and volume (**Figure 6**). This suggests that Panama would have to be more careful in the FTA negotiations and ban certain products from the agreement.

Imported goods´ conditions	**Type of condition**	**MSWS overall check**	**Fulfillment**
$V_{VM} > V_{UM}$	Materials' value	$V_{BPS} > V_{Wastes} + V_{CPS}$	no
$W_{VM} > W_{UM}$	Materials' value	$W_{BPS} > W_{Wastes} + W_{CPS}$	no
$V_{IG} / V_{PPG+UP} \leq 3$	Structural configuration	$V_{BPS} / V_{CWM} \leq 3$	yes
$W_{PPG+UP} \geq W_{GPP}$	Structural configuration	$W_{CWM} \geq W_{BWM}$	yes

Table 1: *Overall fulfilment results for the proposed conditions to imported goods. Abbreviations: V: volume; W: weight; VM: values materials; UM: unvalued materials; IG: imported Goods; PPG: products of the packaged Goods; UP: unpackaged products; GPP: Goods´ primary package; BPC: by-products of the consumer; CPC: co-products of the consumer; BPS: by-products of the system; CPS: co-products of the system; BWM: by-wastes of the manufacturer; CWM: co-wastes of the manufacturer; GMNWV: global market net waste value.*

Local pollution in developing countries derived from the consumption of imported goods could be mitigated through adequate definitions of material flows getting in and out of the importing country and FTA clauses including EPR policies, negotiated between the exporting and importing country, where the responsibility for the MSWSs derived from imported goods is extended beyond local boundaries, to the country of origin.

The proposed methodology could be boosted through the eco-labelling of imported goods, such as the C2C (Cradle to Cradle) system (Llorach-Massana et al., 2015). This could help the importing country in assessing whether the imported goods fulfill the conditions drawn up and laid down in FTAs clauses and decide whether or not to ban goods with environmentally unfriendly packaging or unsustainable life-cycle outcome. Eco-labelled goods should be preferred over others if the objective is to increase the efficacy of the EPR clause of the FTAs.

Like is the case with Panama, many non-industrialized countries –notably in Latin-America– are facing a dramatic increase in resource consumption, where the vast majority of the goods consumed is imported from industrialized economies, a large part through FTAs (Saltelli et al., 2015). While industrialized economies have locally well-established MSW management systems, in non-industrialized countries MSW management systems are still incipient. FTAs encouraging waste generation in non-industrialized economies through indiscriminate and rapidly expanding imports of consumer goods represent an indirect polluting license and cannot be ignored by industrialized economies when committing to such agreements. Industrialized economies should assume responsibility when exporting consumer goods to non-industrialized economies with poorly developed waste management systems, while non-industrialized economies should demand the application of adequate EPR policies before signing an FTA.

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A. Appendix

Imported goods´ types index*	**Imported goods´ types**
C1	Animal
C2	Vegetable
C3	Oils/grease/wax
C4	Industrial food/alcohol/tobacco
C5	Minerals
C6	Chemical
C7	Plastic/Rubber
C8	Leather/skin/fur
C9	Wood
C10	Cellulose
C11	Textile
C12	Ceramic/glass
C13	Precious stones
C14	Metal
C15	Electric/electronic
C16	Vehicles
C17	Clinical
C18	Weapons
C19	Various
C20	Art

Table A1. Imported goods´ types to Panama through FTAs with industrialized economies. ** Index used through this study to refer to imported good types*

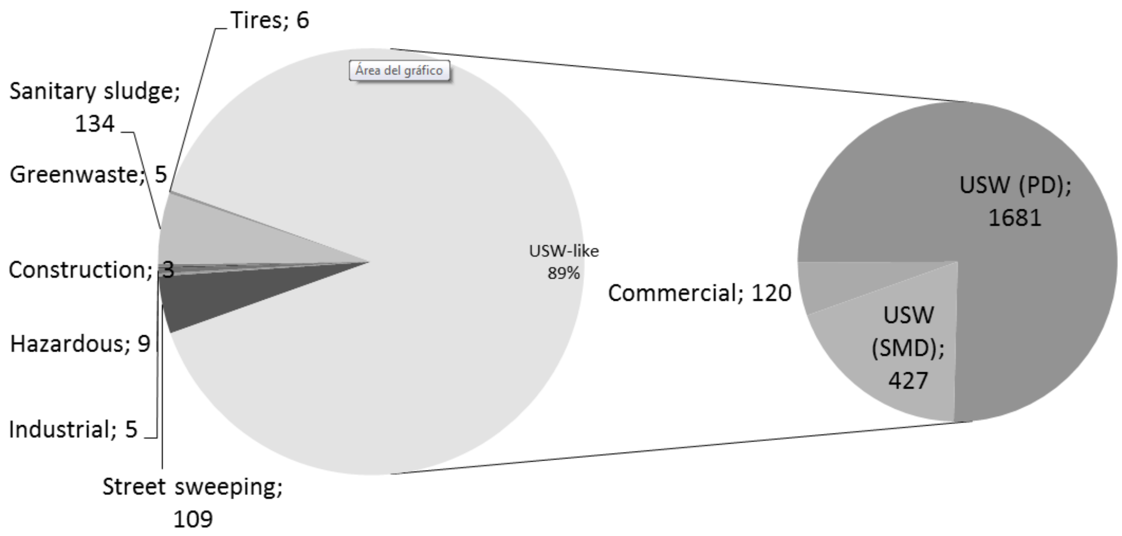

Figure A1. Fractions of all waste disposed in the Cerro Patacón landfill (t/d).

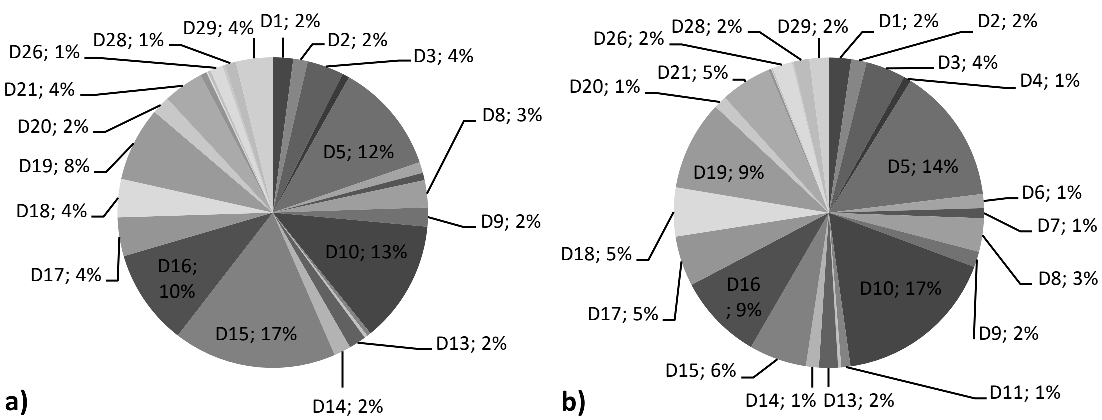

Figure A2. Proportions of the MSWS fractions from the household sector of the Panama district disposed of in Cerro Patacón as a: a) (w/w) and b) (v/v). *Percentages less than 1% have been omitted for space reasons.

Disposed MSW fractions Index**	Description	Materials	Constitutive part	Material value
D1	Bottle/jar package as container for beverage products	Polyethylene terephthalate (PET)	GPP	VM

D2	Bottle/jar package as container for household chemicals	High-Density Polyethylene (HDPE)	GPP	VM
D3	Dish/glass package as foam container for food and beverages products	Expanded polystyrene (EPS)	GPP	UM
D4	Family size packages as container for liquid products	Diverse plastics types	GPP	VM
D5	Plastic films for single-use bags	Low-Density Polyethylene (LDPE)	GPP	VM
D6	Cartoon with Tetra Pak® technology as container for beverage products	Tetra Brik®	GPP	VM
D7	Multi-layer bag as container for food and beverage products	Complex laminates	GPP	VM
D8	Metal can as containers for beverage products	Steel/Aluminum	GPP	VM
D9	Bottle as container for beverage products	Glass	GPP	VM
D10	Cartoon as container for beverage and packaging products	Cardboard	GPP	VM
D11	Crates as container for fruits and vegetables	Wood	GPP	UM
D12	Tubing and hydraulic application accesories	Polyvinyl Chloride (PVC)	UP	VM
D13	Non-container applications waste	Diverse plastics	PPG	VM
D14	Non-container application waste	Steel/Aluminum	PPG	VM
D15	Household kitchen food waste	Food rest	UP	UM

D16	Household gardens green waste	Ligneous/non-ligneous raw	UP	UM
D17	Disposable kitchen/toilet paper waste	Lignocellulosic biomass	PPG	UM
D18	Disposable absorbent wearable waste	Sanitary pad/diapers	PPG	UM
D19	Rags/clothes/leather/wood fragments waste	Textile/leather/wood	PPG	UM
D20	Minor construction/earthenware, pottery and porcelain waste	Concrete/brick/Ceramic/Clay	PPG	UM
D21	Writing and printing paper waste	Lignocellulosic biomass	PPG	VM
D22	Kitchen, automobile or commercial used lipophilics/hydrophics liquids	Oil	PPG	UM
D23	Electrochemical cells device waste	Batteries	PPG	VM
D24	Household application chemicals	Chemical substances	PPG	UM
D25	Medical application materials waste	Diverse materials	PPG	UM
D26	Electrical/electronic appliances/cables/CFL components waste	Waste of Electrical and Electronic Equipment (WEEE)	PPG	VM
D27	Vehicle wheels rim cover waste	Tires	UP	UM
D28	Non-container application voluminous waste	Diverse materials	UP	UM
D29	Fine refuse/earth/stones/glass bottle cullets waste (<20 mm)	Diverse materials	UP	UM

Table A3. Fractions of the MSWS of the household sector of the Panama district, materials, constitutive parts and material value as per the global market net waste value. *** Index used through this study referring to disposed MSW fractions.*

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Disposed	*Organic/inorganic materials (Landva and Clark, 1990)*	*Composition of material groups (DEQ, 2004)*	*Size and dimension of material groups (Dixon and Langer, 2006)*	*Degradability (Dixon and Langer, 2006)*	*IPCC classification (IPCC, 2000)*
D1	Non-Putrescible organic	Plastic	Flexible plastic	Very difficult/ non-degradable	Plastic
D2	Non-Putrescible organic	Plastic	Flexible plastic	Very difficult/ non-degradable	Plastic
D3	Non-Putrescible organic	Plastic	Flexible plastic	Very difficult/ non-degradable	Plastic
D4	Non-Putrescible organic	Plastic	Flexible plastic	Very difficult/ non-degradable	Plastic
D5	Non-Putrescible organic	Plastic	Flexible plastic	Very difficult/ non-degradable	Plastic
D6	Non-Putrescible organic	Mixed	Paper/ cardboard	Medium difficult	Paper/ cardboard
D7	Degradable inorganic	Plastic	Flexible plastic	Very difficult/ non-degradable	Other
D8	Degradable inorganic	Metal	Metal	Very difficult/ non-degradable	Metal
D9	Non-Degradable inorganic	Glass	Mineral	Very difficult/ non-degradable	Glass
D10	Non-Putrescible organic	Paper	Paper/ cardboard	Medium difficult	Paper/ cardboard
D11	Non-Putrescible organic	Organic	Wood/leather	Difficult	Wood

D12	Non-Putrescible organic	Plastic	Rigid plastic	Very difficult/ non-degradable	Plastic
D13	Non-Putrescible organic	Plastic	Rigid plastic	Very difficult/ non-degradable	Plastic
D14	Degradable inorganic	Metal	Metal	Very difficult/ non-degradable	Metal
D15	Putrescible organic	Organic	Organic	Easy	Food waste
D16	Putrescible organic	Organic	Organic	Easy	Wood
D17	Non-Putrescible organic	Paper	Paper/ cardboard	Medium difficult	Paper/ cardboard
D18	Non-Putrescible organic	Organic	Miscellaneous	Medium difficult	Other
D19	Non-Putrescible organic	Organic	Wood/leather	Very difficult/ non-degradable	Textiles - Rubber/ Leather
D20	Non-Degradable inorganic	Inorganic	Mineral	Very difficult/ non-degradable	Other
D21	Non-Putrescible organic	Paper	Paper/ cardboard	Medium difficult	Paper/ cardboard
D22	Non-Putrescible organic	Hazardous	Miscellaneous	Medium difficult	Other
D23	Degradable inorganic	Hazardous	Miscellaneous	Very difficult/ non-degradable	Other

D24	Non-Putrescible organic	Hazardous	Miscellaneous	Medium difficult	Other
D25	Non-Putrescible organic	Inorganic	Miscellaneous	Very difficult/ non-degradable	Other
D26	Degradable inorganic	Metal	Miscellaneous	Very difficult/ non-degradable	Other
D27	Non-Putrescible organic	Organic	Rigid plastic	Very difficult/ non-degradable	Rubber/ Leather
D28	Non-Putrescible organic	Organic	Miscellaneous	Difficult	Other
D29	Non-Degradable inorganic	Inorganic	Mineral	Very difficult/ non-degradable	Other

Table A4. Fractions of the MSWS of the household sector of the Panama district classified according to various classification systems regarding structural properties.