Harvesting the Plastic We Have Sowed:
Costs and Challenges in, and a Novel Application of Blockchain for Implementing Extended Producer Responsibility in Chile

by

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Submitted to the Integrated Design and Management Program on May 18, 2018, in partial fulfillment of the requirements for the degree of

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Abstract

Cities and peri-urban areas are disproportionately large producers of solid waste in an increasingly landfilled world with plastic-choked oceans. Managing waste sustainably remains a challenge, and an expensive one, often comprising 20%–50% of municipal budgets. In the last 25 years, Extended Producer Responsibility (EPR) has emerged as an environmental policy approach in which a producer's responsibility for a product is extended to throughout its lifecycle, beyond the point of sale to the post-consumer stage. This thesis analyzes the effects of soon-to-be implemented EPR in Chile.

Using packaged beverage PET bottles as a case study, it models the per-bottle cost of implementing EPR. The thesis explores the effect of EPR on the recycled PET market and its main substitute and competition virgin PET. It also considers how might EPR's implementation incorporate Chile's informal waste picking labor force.

It proposes an integrated waste management system that connects "smart" (IoT) delivery points, base-recycler-facing mobile-phone applications, and producers', retailers, and recyclers' inventory systems on an integrated public permission blockchain that tracks the flow of products, and measures and rewards every agent's contribution to proper waste management in a transparent, reliable, and ground-breaking way. Such an application of a blockchain does not yet exist and could prove to be an effective and empowering technology for implementing EPR.

Thesis Supervisor: Roberto Rigobon
Title: Society of Sloan Fellows Professor of Management; Professor, Applied Economics, MIT Sloan School of Management

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- Adi, for challenging me;
- Ravi Gopinath, for seeing me;
- Savita and Anand Sekhri, for everything.

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I sat upon the shore
Fishing, with the arid plain behind me
Shall I at least set my lands in order?

- T.S. Eliot, The Waste Land

Introduction

Cities and peri-urban areas are disproportionately large producers of solid waste in an increasingly landfilled world with plastic-choked water bodies. The world is rapidly urbanizing, which creates associated runoff problems, such as municipal solid waste generation. According to the 2012 World Bank report on solid waste management, the world's municipal solid waste (MSW) growth rate is higher than our rate of urbanization. The report estimates that the average urban residents' solid waste generation has doubled in ten years between 2002 and 2012, from about 0.64 kg/1.4 lbs. of MSW per person per day in 2002 to about 1.2 kg/2.65 lbs. per person per day. They estimate that by 2025, 4.3 billion urban residents will each generate about 1.42 kg/3.13 lbs. of municipal solid waste per day[1].

As with most things, residents in developing countries, especially the urban poor, are more severely impacted by unsustainably managed municipal waste than those in developed countries. In low and middle-income countries, waste is often disposed in unregulated dumps or openly burned, creating serious health, safety, environmental consequences. Poorly managed waste acts as breeding ground for disease, contributes to global climate change through methane generation, and even promotes urban violence, through reinforcing perception of neglect and through blocking access to high-crime areas. This happened in Kingston, Jamaica in 2010 when large waste items were used to block off a community's access to police during riots[2,3].

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[1] Daniel Hoornweg and Perinaz Bhada-Tata, "What a Waste: A Global Review of Solid Waste Management," *World Bank*, Urban Development, 15 (March 2012), https://openknowledge.worldbank.org/handle/10986/17388.

[2] Marc Lacey, "Unrest Grows in Jamaica in 3rd Day of Standoff," *The New York Times*, May 26, 2010, https://www.nytimes.com/2010/05/26/world/americas/26jamaica.html.

[3] S. Kaza and F. Banna, "What Does Waste Management Have to Do with Reducing Crime and Violence in Jamaica?," *World Bank Sustainable Cities* (blog), November 2014,

Despite the non-uniform access to waste management around the world, there are some widely understood concepts around waste management, given the universality of the problem. One important one is the Waste Hierarchy, which presents an order of preference for actions to manage waste that prioritizes sustainability--environment protection, and reduction in resource and energy consumption. It is usually presented as a pyramid, and emphasizes the "3 Rs": Reduce, Reuse, and Recycle, in reducing order of preference.

Managing waste sustainably remains a challenge for both developed and developing cities and countries. It is also expensive, often comprising 20%–50% of municipal budgets[4]. From the same report, these charts below reveal a sobering truth that despite the ubiquitous prevalence of the universal recycling symbol on on products around the world since 1970, in most countries, less than 1% of our waste is actually recycled.

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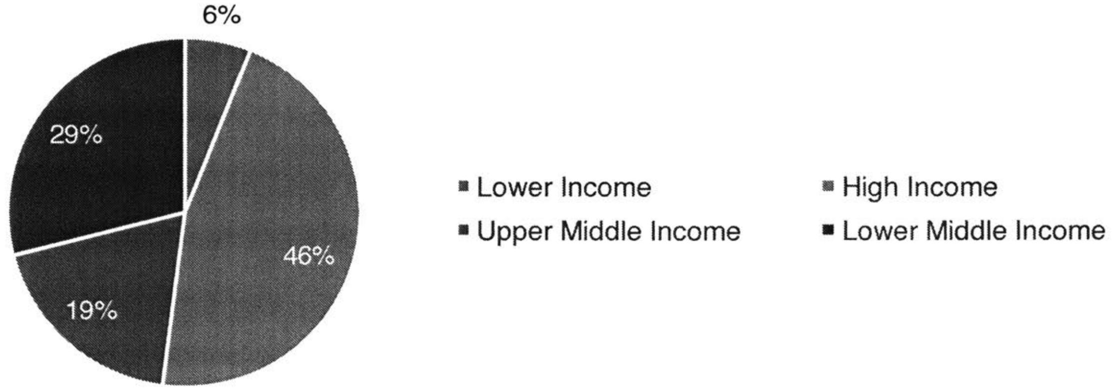
http://blogs.worldbank.org/sustainablecities/what-does-waste-management-have-do-reducing-crime-and-violence-jamaica.

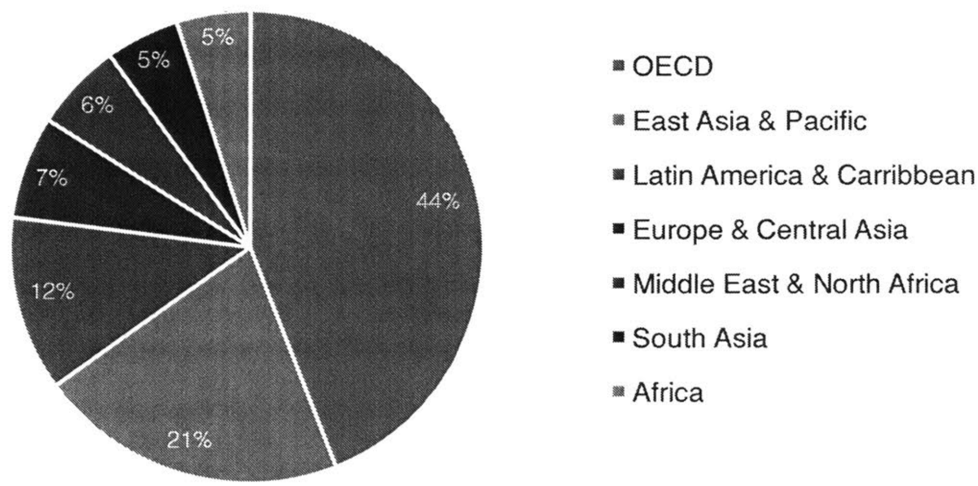
[4] Daniel Hoornweg and Perinaz Bhada-Tata, "What a Waste: A Global Review of Solid Waste Management".

Figure 1: Municipal Waste Generated by Income



[5]

Figure 2: Municipal Waste Generated by Region



[6]

Income Level	Waste Generation Per Capital (kg/capita/day)

[5] Daniel Hoornweg and Perinaz Bhada-Tata, "What a Waste: A Global Review of Solid Waste Management".

[6] Daniel Hoornweg and Perinaz Bhada-Tata, "What a Waste: A Global Review of Solid Waste Management".

	Lower Boundary	Upper Boundary	Average
High		14	2.1
Upper Middle	.11	5.5	1.2
Lower Middle	.16	5.3	.79
Lower	.09	4.3	.60[7]

Municipal Solid Waste Disposal by Income			
High Income		Upper Middle Income	
Dumps	0.01%	Dumps	32.4%
Landfills	42.5%	Landfills	58.9%
Compost	11.2%	Compost	0.9%
Recycled	21.9%	Recycled	1.4%
Incineration	20.7%	Incineration	0.1%
Other	3.6%	Other	6.2%
Low Income		Lower Middle Income	
Dumps	12.6%	Dumps	48.8%
Landfills	59%	Landfills	11%
Compost	1.3%	Compost	2.2%
Recycled	0.5%	Recycled	5.2%
Incineration	1.3%	Incineration	0.2%
Other	26%	Other	32.5%[8]

Predictably, global waste trade exists, and the flow of materials are usually from the Global North to the Global South[9], especially as environmental and social standards become costlier in developed countries, leading to dump sites such as Agbobloshie, in Ghana, which gained notoriety for its alarmingly high e-waste toxicity.

[7] Daniel Hoornweg and Perinaz Bhada-Tata, "What a Waste: A Global Review of Solid Waste Management".

[8] Daniel Hoornweg and Perinaz Bhada-Tata, "What a Waste: A Global Review of Solid Waste Management".

[9] Roberto Sánchez, "International Trade in Hazardous Wastes: A Global Problem with Uneven Consequences for the Third World," *Journal of Environment & Development: A Review of International Policy Produced at the University of California*, 1994, http://journals.sagepub.com/doi/pdf/10.1177/107049659400300110.

The Hitchhiker's Guide to the Galaxy says one of the simplest and most effective (force) fields in the universe is the Somebody Else's Problem (SEP) field:

> "*An SEP is something we can't see, or don't see, or our brain doesn't let us see, because we think that it's somebody else's problem.... The brain just edits it out, it's like a blind spot. If you look at it directly you won't see it unless you know precisely what it is. Your only hope is to catch it by surprise out of the corner of your eye... it relies on people's natural predisposition not to see anything they don't want to, weren't expecting, or can't explain.*[10]"

Waste is a classic SEP. But it is also an economy, with land, labor, and capital goods, and materials, energy and service inputs. In most places of the world, it is informal, unrecorded, unreported, and some times even illegal. It has externalities, and a labor force, but neither are recognized as such. As with other grey economies, regulation can be an effective conduit to formalize this market, price and internalize its externalities, and measure its performance.

This thesis considers the effects of a new environmental regulation, Extended Producer Responsibility (EPR), in Chile, in which a producer's responsibility for a product is extended to throughout its lifecycle, beyond the point of sale to the post-consumer stage. Using PET bottles as a case study, it models the per-bottle cost of implementing EPR in 2019. It also investigates the effect of EPR on the market for recycled PET, and on informal recyclers. It finally proposes that a public permission blockchain recording an integrated waste management system could be an effective and empowering technology and management system for EPR implementation, which would bring light to this hidden economy.

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[10] Douglas Adams, *The Hitchhiker's Guide to the Galaxy* (New York: Harmony Books, 1980).

Part I: Background

1.1 Regulation and Waste

"If I ascend up into heaven, you are there:
if I make my bed in Sheol, behold, you are there[11]."

The valley of Sheol/ Gehenna is understood to have had periodic burning of rubbish outside the city of Jerusalem. Humans have always created waste but as long as it was biodegradable and in areas of low density, it did not present a significant challenge. The industrial revolution gave rise to new consumption and urbanization patterns, and waste, and its associated effects on public health, evident through the Cholera outbreaks, became a concern.

Waste management has a close link with governance and the law, which is reasonable, given waste is a negative externality and the classic tragedy of the commons. Social reformer Edwin Chadwick's 1842 report The Sanitary Condition of the Labouring Population was influential in passing new legislation, the Nuisance Removal and Disease Prevention Act of 1846[12], that set up the first regulated waste management in London. New York City became the first city in the United States with public sector garbage management in 1895.

These laws range from the municipal, national, to inter-state levels. For instance, European Union Parliament's Directive 2008/98/EC obliges member states to introduce into national waste management laws a new five-step waste hierarchy of waste prevention, reus, recycling, recovery (material, and energy recovery), and as a last

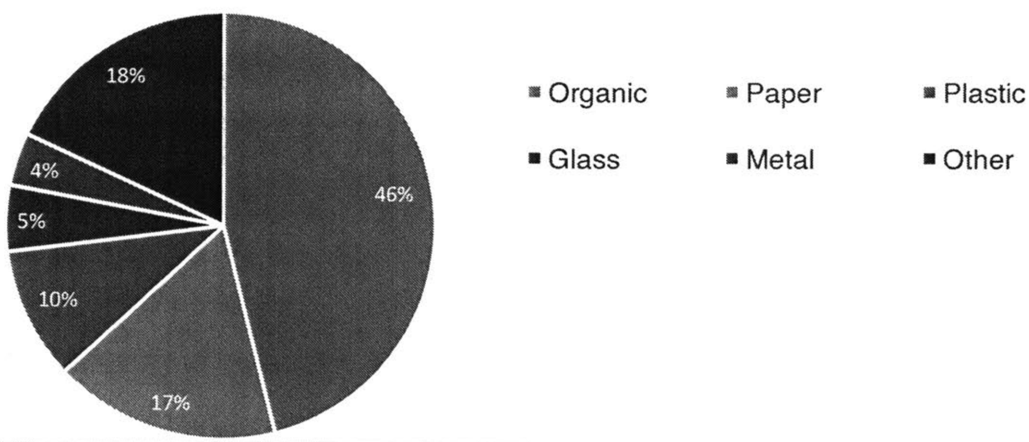
[11] *King James Bible*, n.d., http://biblehub.com/kj2000/psalms/139.htm.
[12] Christopher Hamlin, "Edwin Chadwick and the Engineers, 1842-1854: Systems and Antisystems in the Pipe-and-Brick Sewers War," *Technology and Culture* 33, no. 4 (1992), http://www.homepages.ucl.ac.uk/.

option, safe disposal. The Basel Convention, ratified by 172 countries in 1989, deprecates movement of hazardous waste from developed to less developed countries (nuclear waste, although hazardous, does not fall under this).

1.2 Plastics and Waste

Globally, plastics are third largest municipal waste source, representing 10% share of the total weight. Although this is a much smaller share than Organic and Paper wastes' respective 46% and 17%, unlike the two, plastics are not biodegradable, and recycled at a very low rate, and therefore present a lasting and growing problem.

Figure 3: Global Solid Waste Composition



13

Over 90% of plastics produced today are "virgin," or derived directly from fossil feedstocks, which amounts to about 6% of annual global oil consumption, equivalent to

[13] Daniel Hoornweg and Perinaz Bhada-Tata, "What a Waste: A Global Review of Solid Waste Management".

the annual consumption of the global aviation industry[14]. If we managed our plastic streams better, a lot of this dependence on virgin plastic could be reduced. And while we fail to do so, each year, we leak at least 8 million tons of plastics—one garbage truck's worth per minute—into the ocean- one garbage truck into the ocean every minute. This rate is expected to double by 2030 and quadruple by 2050[15].

Our oceans are choked. They are expected to contain 1 ton of plastic for every 3 ton of fish by 2025, and by 2050, more plastics than fish (by weight)[16]. More than 30 years after it was discovered, we continue to contribute to the Great Pacific Garbage Patch was discovered. At the same time, microplastics, which are particles of plastics less than 1mm in size, pose a new challenge. Microplastics are found in cosmetics, or are formed when plastics degrade over time and are inconspicuously entering the food chain. They have been found in over a third of all fish caught in the UK[17], and recently, a study estimated that seafood eaters ingest up to 11,000 pieces of microplastics every year[18].

Polyethylene Terephthalate, commonly known as PET, is the most used and produced polymer in the world. It has extensive use in the textile industry, where it is more commonly known as Polyester, and the rest for packaging. The market for PET Resin is

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[14] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics" (World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, 2016), https://newplasticseconomy.org/publications/report-2016.

[15] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics".

[16] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics".

[17] A.L. Lusher, M. McHugh, and R.C. Thompson, "Occurrence of Microplastics in the Gastrointestinal Tract of Pelagic and Demersal Fish from the English Channel," *Marine Pollution Bulletin* 68, no. 1–2 (February 2013): 15.

[18] L. Van Cauwenberghe and C.R. Janssen, "Microplastics in Bivalves Cultured for Human Consumption," *Environmental Pollution*, 2014, 65–70.

dominated by drinks- Carbonated soft drinks (CSD), bottled water, and other drinks make up over 70% of global PET consumption. Globally, beverage bottles represent at least 16% of the plastic packaging market (by weight)[19].

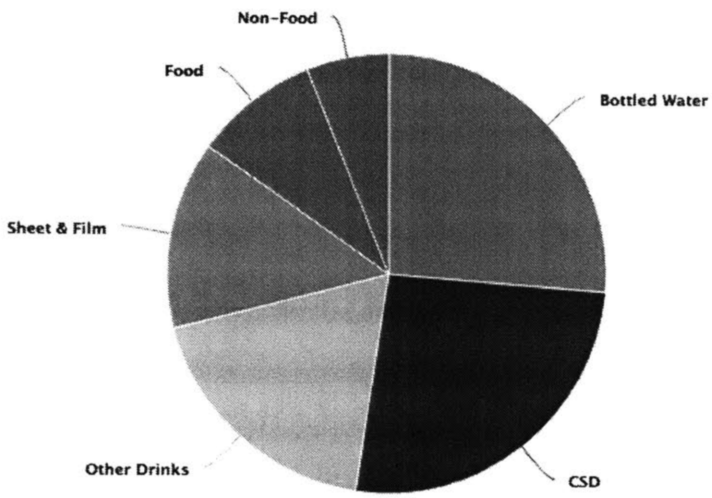

Figure 4: Global PET Consumption by Product Type[20]

Global nonprofit Ocean Conservancy, in their beach clean-ups around the world, found that out of almost 14 million items collected, five of the ten most commonly found items (by the number of items found) are plastic packaging, and plastic beverage bottles the second most common type of item[21].

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[19] Ellen Macarthur Foundation, "The New Plastics Economy – Catalyzing Action" (World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, 2017), https://newplasticseconomy.org/assets/doc/New-Plastics-Economy_Catalysing-Action_13-1-17.pdf.

[20] "Polyethylene Terephthalate (PET): Production, Price, Market and Its Properties," plasticinsight.com, 2017, https://www.plasticsinsight.com/resin-intelligence/resin-prices/polyethylene-terephthalate/.

[21] Ocean Conservancy, "Together for Our Ocean – International Coastal Cleanup 2017 Report," 2017, https://oceanconservancy.org/wp-content/uploads/2017/04/2017-Ocean-Conservancy-ICC-Report.pdf.

Despite being the most recyclable compound in the world, and despite the ubiquity of the universal recycling symbol, less than 3.5% of PET bottles globally are made of recycled PET (rPET).

1.3 What is EPR?

The 2001 OCED EPR Guidance Manual considers Extended Producer Responsibility (EPR) as "an environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle. There are two related features of EPR policy: (1) the shifting of responsibility (physically and/or economically; fully or partially) upstream to the producer and away from municipalities, and (2) to provide incentives to producers to incorporate environmental considerations in the design of their products."[22]

The Manual identified four goals of EPR policies:

i) Source reduction (natural resource conservation/materials conservation)
ii) Waste prevention
iii) Design of more environmentally compatible products
iv) Closure of materials use loops to promote sustainable development

EPR was introduced by environmental economist Thomas Lindhqvist in a report to the Swedish Ministry of environment in 1990. It has subsequently been adopted legally in different formats by many countries, and in other places, voluntarily by different companies and industry associations.

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[22] Daniel Kaffine and Patrick O'Reilly, "What Have We Learned About Extended Producer Responsibility in the Past Decade?- A Survey of the Recent EPR Economic Literature." (Environment Policy Committee – Environment Directorate, OECD, Working Party on Resource Productivity and Waste. OECD, January 21, 2015), http://spot.colorado.edu/~daka9342/OECD_EPR_KO.pdf.

Policies considered under the framework of EPR include:

i) product take-back with recycling targets,

ii) deposit/refund,

iii) advanced disposal fees (ADF),

iv) virgin materials taxes,

v) upstream combination tax/subsidy (UCTS),

vi) recycling content standards. [23]

1.4 EPR's adoption, environmental efficacy, and performance

Since its introduction, and increasingly over the past 15 years, EPR policies have been implemented in over 400 different formats globally, most of them in OECD countries.

[23] Daniel Kaffine and Patrick O'Reilly, "What Have We Learned About Extended Producer Responsibility in the Past Decade?- A Survey of the Recent EPR Economic Literature".

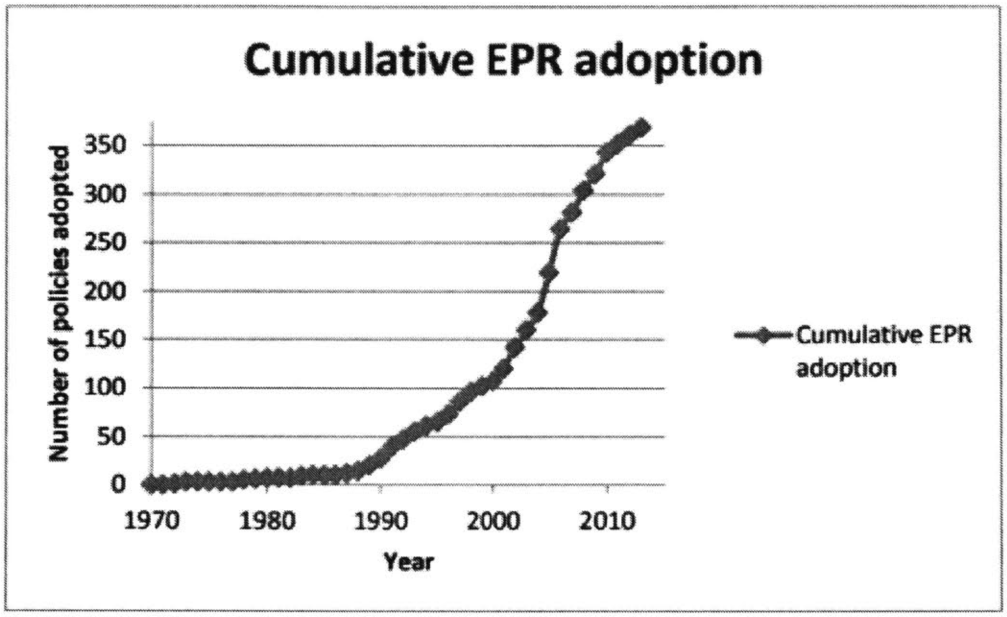

Figure 5: Cumulative Global EPR Adoption [24]

There is a plethora of literature evaluating the environmental and economic effectiveness of EPR schemes. They are generally found to be net-positive, and the efficacy depends on the policy type.

Take-back requirements and recycling content standards increase the amount of material recycled and the recycling rate, as seen in the 27% increase in recycling rates of containers and packaging waste in Japan over a 4 year period[25]. Another example is an EPR scheme set up in 2003 in Korea which charges an advance disposal fee on

[24] Daniel Kaffine and Patrick O'Reilly, "What Have We Learned About Extended Producer Responsibility in the Past Decade?- A Survey of the Recent EPR Economic Literature".
[25] T. Tasaki, A. Terazono, and Y. Moriguchi, "An Evaluation of the First Five Years After Enactment of the Japanese WEEE Recycling Act and the Current State." (Sardinia 2007, Eleventh International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy: CISA, Environmental Sanitary Engineering Centre, Italy, 2007), https://www.researchgate.net/publication/303912351.

producers and importers of materials and containers that are difficult to recycle. As a result of this scheme, packaging recycling increased by 74%[26].

Market-based policies that incentivize recycling are also be effective. Unsurprisingly, plastic water bottle recycling increases with deposit/refund bottle bills[27] and increasing bottle-bill deposit/refund rates per container increases recycling rates (at least in the U.S.)[28]. In fact, a substantial difference in recycling rates can be observed between states without a deposit/refund (roughly 30%), and those with a deposit/refund (roughly 70%), regardless of the deposit rate[29].

Design for Environment (DfE) is a design approach that considers the entire lifecycle of a product, process, or a service, and designs it to reduce its overall environmental and human health impact. By shifting the onus of a product's end of life management on producers, EPR policies in theory nudge or even directly incentivize producers to design their products with the environment in mind, for example by reducing their weight, packaging, or enhancing recyclability. But there is variability in their ability to do so. A study of 395 EPR schemes concluded that policies that directly target product

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[26] Hyein Heo and Mun-Hee Jung, Case study for OECD Project on Extended Producer Responsibility, Republic of Korea, OECD (2014).

[27] W.K. Viscusi, J. Huber, and J. Bell, "Promoting Recycling: Private Values, Social Norms, and Economic Incentives," *The American Economic Review* 101, no. 3 (2011): 65–70.

[28] B.M. Batson and R.G. Eggert, "Not a 'Waste' of Time: Temporal Recycling Policies Given Household Waste Disposal Actions" (Colorado School of Mines, 2014), https://dspace.library.colostate.edu/bitstream/handle/11124/420/Batson_mines_0052E_10432.pdf?sequence=1.

[29] B.M. Batson and R.G. Eggert, "Not a 'Waste' of Time: Temporal Recycling Policies Given Household Waste Disposal Actions".

characteristics (such as weight, recyclability, etc.) most incentivized for eco-design changes[30].

Another finding is that collective schemes, in which a Producer Responsibility Organization (PRO) is set up to implement the EPR scheme on behalf of several adhering companies, are less likely to lead to designing for environment than schemes in which producers are individually responsible for their products, since the responsibility is shared and therefore the impact and incentive effect on individual producers is limited[31]. In individual schemes producers pay the full cost of the waste management for their products. In collective schemes different types of products will have varying waste management costs and valorization returns, but it can be complicated to deduce exact attribution, which leads to an 'averaging' effect on collective fees,[32] which generally provides lesser incentive for eco-design to each producer and more frequent free-riding where some producers do not pay their full share[33].

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[30] Daniel Kaffine and Patrick O'Reilly, "What Have We Learned About Extended Producer Responsibility in the Past Decade?- A Survey of the Recent EPR Economic Literature".

[31] G. Eduljee, "'Why EPR?,'" September 6, 2017.

[32] "'Redesigning Producer Responsibility - A New EPR Is Needed for a Circular Economy.' Zero Waste Europe" (Brussels: Zero Waste Europe, 2015), https://zerowasteeurope.eu/downloads/redesigning-producer-responsibility-a-new-epr-is-needed-for-a-circular-economy/.

[33] E. Watkins et al., "EPR in the EU Plastics Strategy and the Circular Economy: A Focus on Plastic Packaging" (Institute for European Environmental Policy, 2017), https://ieep.eu/uploads/articles/attachments/95369718-a733-473b-aa6b-153c1341f581/EPR%20and%20plastics%20report%20IEEP%209%20Nov%202017%20final.pdf?v=63677462324.

A surprising benefit of EPR policies is that income provided by bottle bill refunds may generate positive externalities of reduced petty crime rate through an accessible source of revenue for low-skilled people.[34]

It is possible EPR policies create other economic costs or "deadweight loss", especially if the burden of the policy is transferred to consumers, in form of lost consumer surplus, or causes lost producer surplus. In theory, shifting the financial burden of waste management from local municipalities to producers should be beneficial only if the operating costs were less for producers than local municipalities, or if process releases some leaking material economy.

1.5 Why EPR in Chile? Rise to OECD setting the context

The Organization for Economic Cooperation and Development (OECD), an intergovernmental economic development organization formed in 1961, has the mission to "promote policies that will improve the economic and social well-being of people around the world." Its 35 member countries are high-income economies with high Human Development Indices.

After a three-year review period, Chile became the first South American country to join, or as OECD puts it, "accession to", the OECD in 2010. In the February of the same year, Chile enacted a law that created its Ministry of Environment, and several other environmental agencies such as the Environmental Evaluation Service, the Ministerial Council for Sustainability. This was a step, among several others, that Chile had to take in order to meet OECD standards and guidelines. In her speech following the signing of the Terms of Accession Agreement, Chilean President Michelle Bachelet remarked,

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[34] B. Ashenmiller, "Externalities from Recycling Laws: Evidence from Crime Rates.," *American Law and Economics Review* 12, no. 1 (2010): 245–261.

"...it is also worth noting that Chile's accession to the OECD is by no means fortuitous. It is the outcome of our ability to construct state policies—the capacity of our democracy to construct and renew major national accords, without which the country cannot progress.[35]"

In its 2015 annual municipal waste review for its member countries, OECD reported that in 2013, Chile and Turkey were the only OECD countries disposing their waste almost entirely in landfills, without any material or energy recovery. In 2016 Chile became the first Latin American country to enact (pass) the Recycling and Extended Producer Responsibility Law. The expressed intention of the law was to create a recycling industry, generate "green" jobs, promote reuse and recycling entrepreneurship, and to formalize the over 60,000 strong grassroots recycling force, through the National Job Skills Certification System. President Bachelet remarked on its passing:

"This is exactly the purpose of the law we are enacting today: to coordinate and systematize the efforts of all stakeholders to reduce pollution and in turn, stimulate the economy.[36]"

1.6 Chile's EPR Law

The law specifies six priority products on which the Ministry of Environment will establish recollection and valorization goals. "Valorization" refers to extracting or creating value from the end product, through either upcycling or recycling the material,

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[35] Michelle Bachelet, "Speech by Her Excellency the President of the Republic, Michelle Bachelet, Following the Signing of the 'Agreement on the of Accession by the Republic of Chile to the OECD Convention,'" January 2010, https://www.oecd.org/chile/44388545.pdf.

[36] "President Bachelet Enacts the Recycling and Extended Producer Responsibility Law," Chilean Government, n.d., https://www.gob.cl/en/news/president-bachelet-enacts-the-recycling-and-extended-producer-liability-law/.

or converting it to energy, or through controlled disposal and regulated sanitary landfills. The six priority product lines are:

i) Lubricant Oils
ii) Electrical and electronic devices
iii) Commercial Batteries
iv) Consumer Batteries
v) Containers and Packaging, and,
vi) Tires

The fifth category, of Containers and Packaging ("Envases y Embalajes," EyE), is further classified into:

i) Paper and Cardboard
ii) Glass
iii) Metals, and,
iv) Plastics

The law shifts the responsibility for waste management upstream from the municipality to the producer. In the case of containers and packaging, "producer" refers to not the producer of the container and packaging, but the producer that "introduces the packaged and packaged goods into the market.[37]" That is, in the case of a Coke bottle bought in a grocery store, the producer refers to Coca-Cola which introduces Coke into the market, and not the manufacturer of the bottle or labels or caps of the Coke bottle. Distributors and retailers are excluded in this version of the law, although producers may enter into agreements with them in order to meet their set goals.

[37] Translated from "Establece Marco Para La Gestíon de Residuous, La Responsibilidad Extendida Del Productor Y Fomento al Reciclaje," Pub. L. No. Ley 20920 (2016), https://www.leychile.cl/Navegar?idNorma=1090894&buscar=20920.

Although the law was passed in 2016, it is yet to be implemented. Industry and government leaders are in discussions to establish the respective recollection and valorization rates for each of the above products, as well as set the rules for labeling, separated delivery, guidelines for eco-design, and reception and storage facilities, among others.

The recovery percentage is supposed to be set, and increase, year on year. The law is applicable to importers as well as domestic producers. Failure to comply could result in fines up to 5.4 Chilean Pesos (CLP), about USD 9.5 million in today's amount.

The law does not oblige producers to set up individual or collective waste management systems, but it recommends that recommends that producers of similar products coordinate their recovery and valorization efforts through the formation and financing of a non-profit Waste Management entity ("Sistema de Gestión", which they refer to as SG, which is more generally known as a Producer Responsibility Organization, PRO) which will interface between Municipalities, Valorization Companies, Producers, and be responsible for recollection efforts and its documentation. The effort would be internally, and externally audited to ensure compliance under the Ministry's guidance.

1.7 Role of Municipalities

The law states that the establishment, operation and maintenance of the waste receptors and storage facilities will be the responsibility of producers or their waste management systems, but they will have to enter into necessary agreements with municipal organizations to seek permits and permissions to operate within municipalities, to use sidewalks, plazas, parks etc.

Municipalities may enter into agreements with the PROs individually or in a group; they may also enter into agreements with "base recyclers," (described below); must make "well-founded" decisions on the requests raised by the PROs; incorporate obligation to separate waste at source and encourage recycling in their municipal ordinances in accordance to the goals set by the law; design and implement communication strategies to raise awareness and promote environmental education in its population; and design and implement strategies to prevent generation of waste.

Article 31 of the law mentions that the Ministry of Environment will have a Fund for Recycling to finance projects, programs and actions to prevent waste, encourage its reuse, recycling and other valorization, and the Fund would be executed by municipalities or municipal organizations.

Waste is primarily a municipal problem, and at least in Chile, it is managed by municipalities in a case-by-case manner. In theory this law strengthens local municipal governments' decision-making authority as global producers will have to comply with and convince each municipality to meet their goals, but it remains to be seen what will be the effects of this global-local dynamics. Interestingly, the law also specifies that the exclusive rights of cleaning and decoration of the municipalities can not be invoked by municipalities to prevent the management of the waste of priority products by the management systems[38].

Currently municipalities cannot legally collect or sell recyclable waste.

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[38] Translated from "Establece Marco Para La Gestíon de Residuous, La Responsibilidad Extendida Del Productor Y Fomento al Reciclaje".

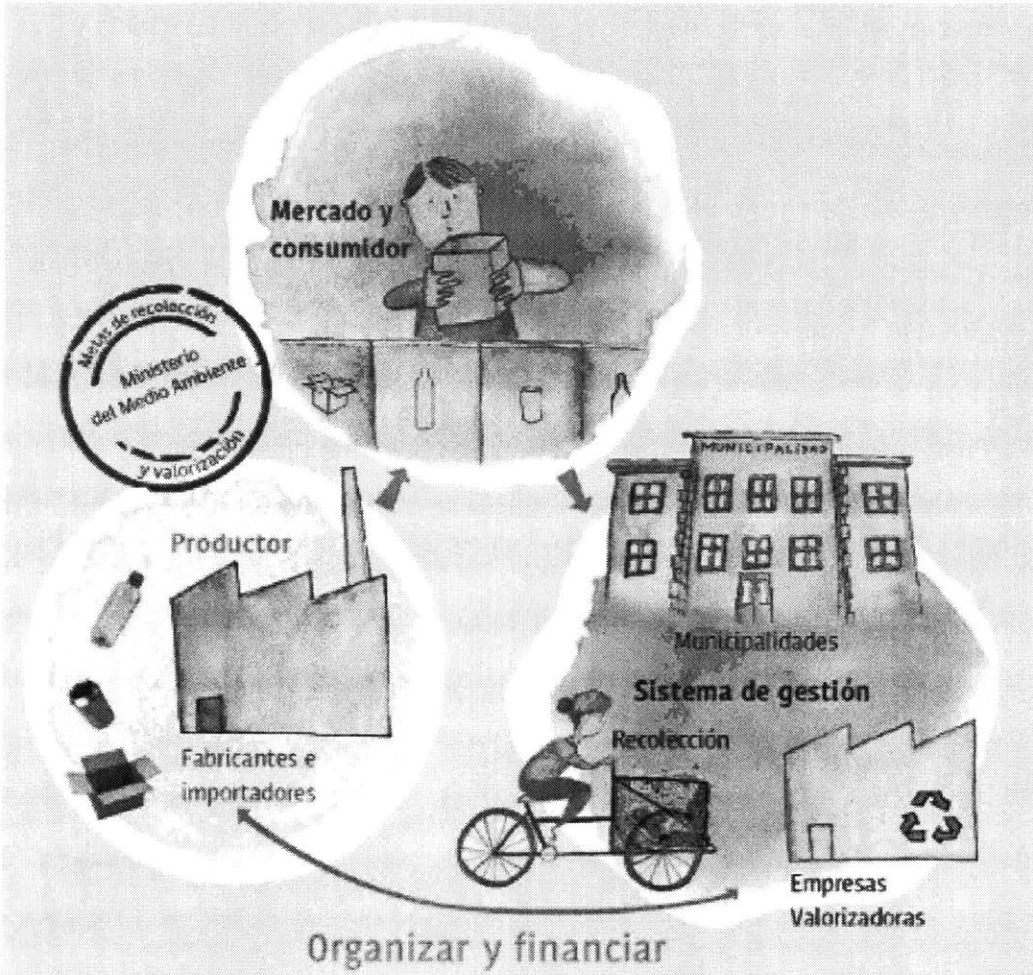

Figure 6: Picture from Chile's Ministry of Environment's website, titled "This is how the Extended Producer Responsibility Works"

1.8 Chile's Current Waste Management Landscape

As in most countries, Chile's waste is publicly managed, and nearly 100% of households have access to public waste disposal through their municipalities, although less than 70% of them actually pay for this service. OECD's second report on Chile's environmental performance from 2005-2015 noted its nearly 30% increase in waste generation, and lack of a recycling industry. It stated that 96% of municipal waste in Chile was deposited in landfills, and only 4% was recovered or recycled in 2010-2011[39].

The majority of non-organic household waste is around packaging and containers. The limited recycling of this waste stream that is prevalent in Chile currently, is because of residents bringing their separated waste into a scattered network of “Puntos Verdes” or Green Points (PVs), and “Puntos Limpios,” Clean Points (PLs).

Green Point (PV) refers to a group of containers in public or private places, that separately receive paper and cardboard, plastic bottles (PET), glass, and sometimes also multicomponent packaging (such as TetraPak), and metals, such as (aluminum cans and tin cans). These are usually not staffed, and are operated either through private recycling companies or through some municipalities with recycling operations.

[39] OECD and United Nations Economic Commission for Latin America and the Caribbean, “OECD Environmental Performance Reviews: Chile 2016” (OECD Publishing, July 21, 2016), http://dx.doi.org/10.1787/9789264252615-en.

Figure 7: Punto Verde" Green Point (PV) in a public place in Chile[40]

Clean Points (PLs) are municipal waste recovery centers which are accessible by cars. They usually have staff attention and can receive a wide variety of waste, such as furniture, appliances, and have a section for recyclable containers like the PVs. In fact, one can think of a PL as an integrated waste delivery/ recovery site, which in turn has a PV.

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[40] Photograph from Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes" (Ministerio del Medio Ambiente, 2012), http://portal.mma.gob.cl/wp-content/doc/Impactos-envases-y-embalajes-2012.pdf.

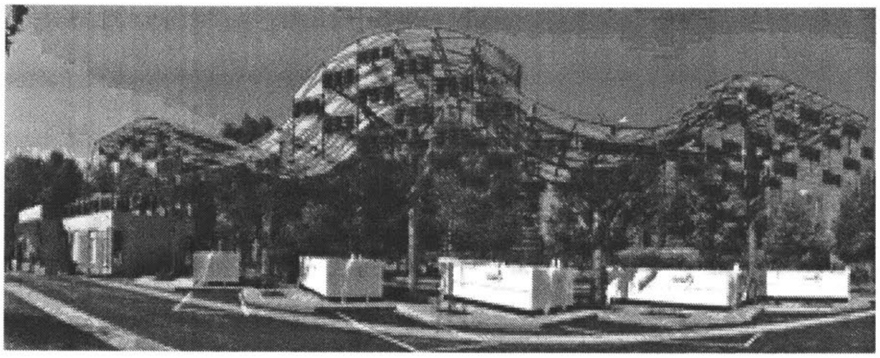


Figure 8: Punto Limpio" Clean Point (PL) in Las Condes, Santiago[41]

The waste from these PVs and PLs is usually sent to a "Centro de Acopio," a Collection Center (CA), to prepare it for transport to its final destination, whether it be to a recycling plant, incinerator, or landfill. Preparation might consist of further separation, and in the case of plastic, paper, cardboard, and metal, also of volume compaction, with the help of compactors and balers.

In 2012, there were eight municipalities that in addition to PLs and PVs, offered door-to-door collection of recyclable waste to some households[42]. Since this waste is received unseparated, it is sent, wherever possible, to a Planta de Clasificación, or a Classification Plant (CPs). These usually consist of a feeding bunker, equipment to open the bags, sieves to separate the finer material, conveyor belts for manual sorting with electromagnets to separate ferrous metals. After separation, the waste follows the same process as in a CA with compaction and baling, and transfer to its valorization destination.

[41] Photograph from Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

[42] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

The following table gives a sense of the size of this network in Chile in 2012:

Municipal Clean Points (PLs)	8
Municipal Green Points (PVs)	30
PVs in retail/malls	100
Other PVs	837
Collection Centers (CAs)	179
Door-to-door collection	8 municipalities[43]

The cost of final disposal of waste in the sanitary landfills of the Metropolitan Region of Santiago ranges between CLP 8,000 and CLP 30,000/ tons, but there are also some some illegal dumps that charge lower fees[44].

Currently municipalities cannot legally collect or sell recyclable waste.

[43] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".
[44] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

Part II: Costs of EPR Implementation on Beverage Producers in Chile

In order to comply with the newly passed ERP law, producers in Chile will have to participate in the waste removal process in order to retrieve and valorize the prescribed percentage of their consumed products.

Naturally, this will cause their costs to increase, and it is likely that this cost will be transferred to consumers as an increase in the price of the products they buy. One way to look at this increase in price is the cost of internalizing the externalities of the product, and coming to reflect the truer cost of the product.

What might be the effects of the implementation of the EPR law in Chile on the cost of a packaged beverage PET bottle?

2.1 EPR implementation system: the material flows

The Chilean Ministry of Environment (Ministerio del Medio Ambiente, MMA) commissioned a report on the economic, environmental, and social effects of the EPR law by the firm Ecoing, which was published in 2012[45]. The report proposes two different scenarios for packaging producers to retrieve their waste and valorize it, and estimates the recovery rate in both scenarios, based on the existing waste collection system in Chile, and on a survey of EPR implementation in different OECD countries.

The report proposes these systems for the assumed first year of implementation, 2016, and supposes that the system would be at scale and full implementation by the fifth year, 2021, under their assumptions. The reality is that the law is yet to be implemented, and in the best case scenario, will be implemented in 2019. So we use the report's first

[45] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

year numbers and assumptions and apply them to 2019 for our analyses. Should the implementation be delayed further, the numbers and logic of this model can be used for any subsequent years.

The expectation is that Packaging waste producers would form and finance a nonprofit Producer Responsibility Organization (PRO), which would either conduct or contract out waste recovery and valorization activities. These PROs could do so in two ways:

Scenario 1
In this scenario, it is assumed that consumers would bring their separated waste to a network of Clean Points and Green Points, from where the waste would be taken to Collection Centers, sorted, baled and transported to valorization sites. In order to retrieve 13% of all PET bottles in 2016, the study estimates the size of the required network to be the following:

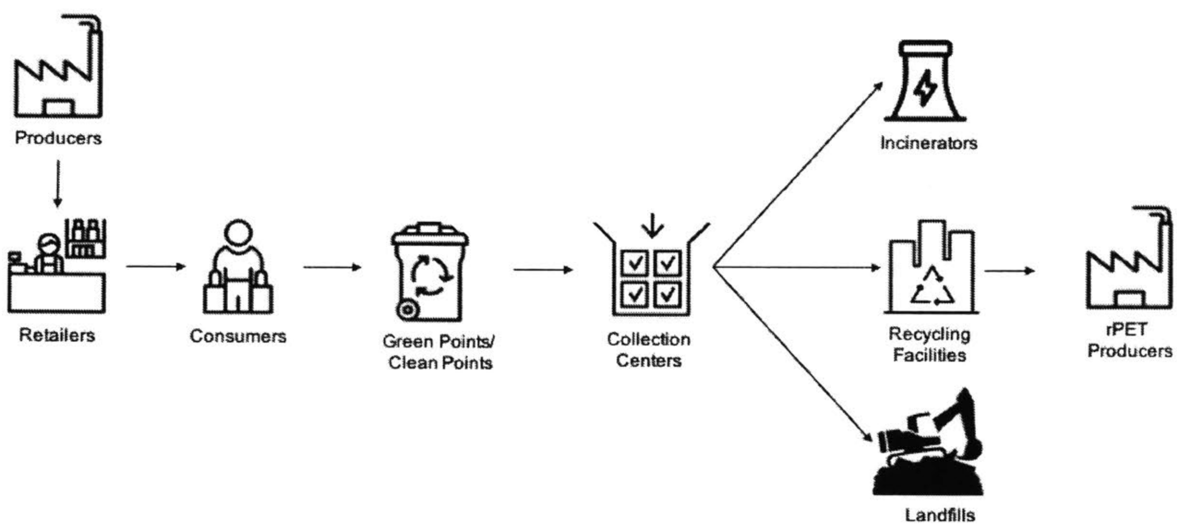
Item	2016	2021	Type of Packaging
New Green Points (PVs)	3,600	7,466	All 5 types (Paper & Cardboard, Glass, Metals, Plastics, Multicomponent)[46]
New Clean Points (PLs)	87	161	
Original No. of PVs	1,000		
Original No. of PLs	8		
Total PV	4,600	7,627	
Total PLs	95		
Total Delivery Points	4,695		
Collection Centers (CAs)	52	89	
Original No of CAs	179		
Total Collection Centers	231		

The expected recovery rate from this scenario are the following:

[46] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

Quantities and rate of recuperation, in Kgs, per delivery point, per month					
Year	Paper & Cardboard	Glass Bottles	Metal	PET Bottles	Multicomponent
2016	1,000	1,000	108	150	50
2021	1,500	1,500	163	225	75[47]

Here's a simplified depiction of this scenario:



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Scenario 2
In this scenario, it is assumed that in addition to a network of PLs, PVs, and CAs, producers of packaging waste would also offer door-to-door collection of light packaging waste (plastics, aluminum cans, and multicomponent packaging such as Tetrapaks), which would then be sent to Classification Plants (CPs), and from there sorted, baled and transported to valorization sites.

[47] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".
[48] Andrejs Kirma et al., *Icons Downloaded from the Noun Project under Creative Commons License*, n.d. (Own diagram)

The study assumes that this additional service would increase the rate of retrieval for the three types of packaging by another 20%, while simultaneously reduce the load to build new PVs and PLs on these three types of packaging waste producers. The study estimates the size of the required network to be the following:

Item	2016	2021	Type of Packaging
New PVs for 5 types of packaging	3,162	1,416	for all 5, in municipalities w/o collection
New PV for 2 types of packaging	438	6,050	for only 2 (glass, paper & carton), in municipalities with collection)
New PLs	87	161	for all 5, in all municipalities
Original No. of PVs	1,000		
Original No. of PLs	8		
Total No of PVs for 5 types of packaging	4,162		5 types of packaging
Total No of PVs for 2 types of packaging	438		2 types of packaging
Total No of PLs	95		all types of packaging
Total delivery points	4,695	7,627	
Collection Centers (CAs)	52	89	3 or 5 types of packaging, based on whether the municipality has door-to-door collection
Original No of CAs	179		
Total No of CAs	231		
Classification Points	3	20	For plastic, metal, multi-component
No of Municipalities w door-to-door collection	10	87	For plastics, metal, and multi-component[49]

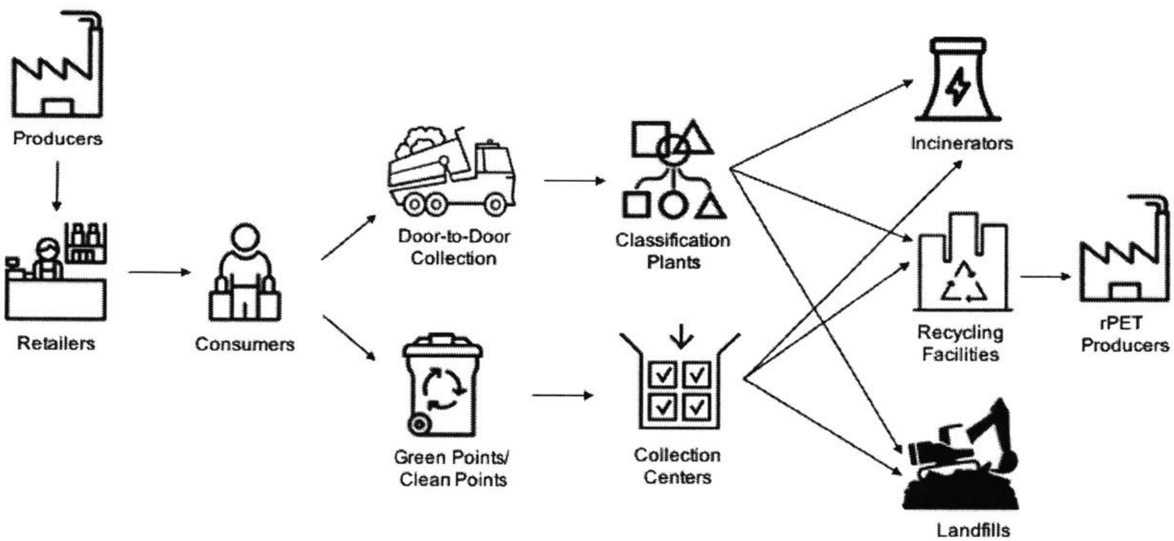
The expected recovery rate from this scenario are the following:

Quantities and rate of recuperation, in Kgs, per delivery point, per month					
Recuperation from PVs, PLs (in kgs/delivery point/month)					
Year	**Paper & Cardboard**	**Glass Bottles**	**Metal**	**PET Bottles**	**Multicomponent**

[49] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

2016	1,000	1,000	108	150	50
2021	1,500	1,500	163	225	75
Recuperation from Door-to-Door Collection (in kgs/delivery point/month)					
2016	No change		+ 20% of the recuperation from PVs, PLs		
2021			+ 40% of the recuperation from PVs, PLs[50]		

Here's a simplified depiction of this scenario:



[51]

Estimating the number of PET bottles in Chile in 2019

The same study presents an estimate of packaging waste generated in Chile from 2002 to 2010 by each of the four sectors, Paper & Cardboard, Glass, Metals, and Plastic. For each sector, it further breaks down the waste by the major types of packaging: for instance, for Metals, it presents the breakup for Pressured Gas Cylinders, Tin Cans, and Aluminum Cans.

[50] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

[51] Andrejs Kirma et al., *Icons Downloaded from the Noun Project under Creative Commons License*, n.d. (Own diagram)

We use the average rate of growth for plastic packaging between these years to project plastic packaging waste in 2019. PET packaging makes up about 15% of all plastic packaging in Chile.

Plastic packaging production in Chile (estimated tons):									
Segment	2002	2003	2004	2005	2006	2007	2008	2009	2010
Plastic Packaging (tons)	254,918	279,585	286,855	337,333	336,554	355,985	347,908	351,409	355,934
% change		9.68%	2.6%	17.6%	0.23%	5.77%	2.27%	1.01%	1.29%
Average % change, 2002 - 2010				**4.43%**[52]					

Projection of Plastic packaging in Chile:									
Segment	2011	2012	2013	2014	2015	2016	2017	2018	2019
Plastic packaging (tons)	371,703	388,170	405,366	423,325	442,079	461,664	482,116	503,475	525,779
Projection of PET packaging in Chile (taking 15% of all Packaging as standard):									
Segment	2011	2012	2013	2014	2015	2016	2017	2018	2019
PET (tons)						69,250	72,317	75,521	**78,867**

Total Packaging production in Chile (estimates):									
Segment	2002	2003	2004	2005	2006	2007	2008	2009	2010
All Packaging (tons)	838,171	900,854	972,174	1,036,787	1,076,835	1,132,072	1,111,368	1,163,647	1,223,264
% change		7.48%	7.92%	6.65%	3.86%	5.13%	1.83%	4.7%	5.12%

[52] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

Average % change, 2002 - 2010	4.88%[53]

Projection of Total Packaging production in Chile:									
Segment	2011	2012	2013	2014	2015	2016	2017	2018	2019
All packaging (tons)	1,282,948	1,345,543	1,411,193	1,480,046	1,552,258	1,627,994	1,707,425	1,790,731	**1,878,102**

PET as % of total packaging waste in Chile in 2019	
Total PET Packaging in 2019, in tons	78,867
All packaging waste in 2019, in tons	1,878,102
Share of PET in all packaging in 2019	**4%**

Here we make an assumption that all PET packaging takes form of PET bottles. This is because we know from above that 70% f PET packaging is in the form of bottles and food-grade packaging. We also know that PET is 100% recyclable. Our goal to have 100% of PET packaging be recycled, and estimate what the cost per container of PET packaging would be in EPR.

We make a second assumption, that the average weight of a PET bottle is 10 grams.

We use the above figures and assumptions to estimate the number of PET bottles that will be sold in Chile in 2019, shown below:

Calculating number of PET bottles sold in Chile in 2019	
Weight of average PET bottle, in grams	10.00
Number of grams in a ton	907,185.00
Weight of average PET bottle, in tons	0.00001102311

[53] Ecoing, “Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes”.

Number of PET bottles in 2019	7,154,688,406

2.2 EPR implementation system: the economic flows

2.2.1 Projecting transportation costs

The same MMA 2012 report also gives us an estimate of freight rates in the country for 2012, which we project to estimate rates in 2019 using a 3% inflation rate.

Freight Type, CLP/ton	2012	2013	2014	2015	2016	2017	2018	2019
Urban (CLP/ton)	40,000	41,200	42,436	43,709	45,020	46,371	47,762	**49,195**
Short (CLP/ton)	60,000	61,800	63,654	65,564	67,531	69,556	71,643	**73,792**
Medium (CLP/ton)	80,000	82,400	84,872	87,418	90,041	92,742	95,524	**98,390**
Long (CLP/ton)	120,000	123,600	127,308	131,127	135,061	139,113	143,286	**147,585**[54]

2.2.2 Projecting Capital, Maintenance, Operational Costs of PVs, PLs, CAs, CPs

The report gives us CLP 5,758,000,000 as an estimate for the maintenance and operation costs for the entire network of PV, PLs in 2016[55]. We know in 2016 it has 87 PLs, and 3600 PVs. We also know the only difference between a PL and PV in terms of operations is the presence of an operator in the PL who supervises and separates the waste. With a monthly salary of CLP 250,000 (wage minimum for 2016), the annual additional expense at a PL over a PV is CLP 3,000,000.

Annual additional expense (3,000,000) x No. of PLs (87) = CLP 261,000,000

[54] Ecoing, “Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes”.
[55] Ecoing, “Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes”.

Total network costs – additional expenses for PL = CLP (5,758,000,000- 261,000,000)

Above number / total number of PV, PLs= (5,497,000,000)/ 3,687) = CLP 1,490,914, which is the maintenance and operation expense for a PV

PV costs + additional expense for PL = (1,490,914 + 3,000,000) = CLP 4,490,914

Having estimated the costs associated per PV and PL in 2016, we can project these using a 3% inflation rate:

Unit capital and maintenance costs per PV: (c/u)						
2016	2017	2018	2019	2020	2021	2022
1,490,914	1,535,641	1,581,711	**1,629,162**	1,678,037	1,728,378	1,780,229
Unit capital and maintenance costs per PL: (c/u)						
2016	2017	2018	2019	2020	2021	2022
4,490,914	4,625,641	4,764,411	**4,907,343**	5,054,563	5,206,200	5,362,386

We also have estimates for processing costs in 2016 for a ton of Plastic waste in a PV and PL, which we project to 2019 using a 3% inflation rate:

Processing and Operations costs for the network of PVs and PLs (for Plastic)				
	2016	2017	2018	2019
CLP/ton	151,218	155,755	160,427	**165,240**

Additionally, it provides us with estimates for processing, capital, and operational costs for the Collection Centers (CAs) and Classification Plants (CPs). The report does not tell us which year these estimates are for, so we assume these are for the year that the report was published (2012) and project them to 2019 using a 3% inflation rate:

Processing, capital, and operational costs (CLP/ ton)								
Type (CLP/ton)	2012	2013	2014	2015	2016	2017	2018	2019

Collection Center	24,620	25,359	26,119	26,903	27,710	28,541	29,398	**30,279**
Type (CLP/ton)	2012	2013	2014	2015	2016	2017	2018	2019
Classification center	155,800	160,474	165,288	170,247	175,354	180,615	186,033	**191,614**

2.2.3 Estimating Landfill Tipping Fee

All landfills charge a tipping fee, which vary vastly, and depend on the landfill. According to the MMA report, "The costs of final disposal of waste in the sanitary landfills of the Metropolitan Region are between CLP 8,000 and CLP 12,000/ ton, and up to $ 30,000/ton, although there are still some illegal dumps that charge lower fees[56]."

Mauricio Ramos, consultant on sustainability and circular economics topics in Santiago, Chile provided the following tipping rates for different landfilling sites in 2018, and we use the above figure of a high of $30,000/ton to estimate an average tipping fee, and project it to 2019 using a 3% inflation rate.

	Tipping Fee, in CLP/ton	
Landfill Company	2018	2019
Emeres, Proactiva	8,930	9,198
Ampliacion Contrato, KDM	10,456	10,770
Emeres, Santa Marta	11,414	11,756
Emeres Gersa	18,355	18,906
Unnamed firm, from MMA 2012 report	30,000	30,900
Average tipping fee	**15,831**	**16,306**[57]

[56] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".
[57] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

2.2.4 Estimating Price paid for Post-Consumer PET bales by recycling plants
This number is not referred to in the report, but it is relevant to us so to determine what the PRO can expect to be paid for its recovery efforts. The price paid for PET bales by plastic recycling plants is highly variable, ranging from "CLP 250/kg to CLP350/kg,[58]" and depends on the color, and quality of the bale. We use an average of CLP 300/kg, which is the same as **CLP 272,155/ton of PET.**

2.2.5 Estimating Administrative Costs for the Producer Responsibility Organization
The PRO will have some associated costs, chief among them the administrative cost of running such a nonprofit, and the costs associated with running a marketing, communications and PR campaign to promote waste recovery in consumers.

In terms of administrative costs, there are costs of paying the workforce, and the expenditures of running an office. Presented below is an estimation of these costs for an office and wages in the commercial neighborhood of Providencia in Santiago:

Office Expenditures	**Monthly (in CLP)**	**Annual (in CLP)**
Rent	2,500,000	30,000,000
Utility bills	500,000	6,000,000
Supplies	250,000	3,000,000
Cleaning	1,000,000	12,000,000
Total	4,250,000	**51,000,000**[59]

Workforce	**Monthly Salary (in CLP)**	**Annual Salary (in CLP)**
General Manager	12,000,000	144,000,000
Logistics	3,500,000	42,000,000
Project Coordinator	3,500,000	42,000,000
Helper 1	2,000,000	24,000,000

[58] Mauricio Ramos, Interview with M. Ramos, April 5, 2018.
[59] Mauricio Ramos, Interview with M. Ramos.

Helper 2	2,000,000	24,000,000
Total Salaries	23,000,000	276,000,000
Total Administrative costs (Office + Workforce)	27,250,000	**327,000,000**[60]

Projections, using a 3% inflation rate:

	2018	2019	2020
ADM	327,000,000	**336,810,000**	336,810,000

2.2.6 Estimating Marketing and Communications Costs for PRO:

The report notes that in order to meet its ambitious goals, a lot of investment has to be made in education and marketing. For instance, in Germany almost 5% for the costs associated with the entire EPR system were for education and communication[61]. Accordingly, in our model, for each scenario, we include an education and marketing cost (COM) that represents **5% of the entire cost of the system** to the PET Producers.

2.2.7 Some more assumptions

1. Producers of packaging waste will collectively fund the non-profit that will manage the recovery and valorization of the waste. This makes intuitive sense because consumers in Chile, as in most places, combine their trash, and only do minimal separation. Since their waste will be collected together, it makes sense for the EPR-regulated producers of packaging waste to combine their efforts in their products' recovery and valorization. Indeed, "among the diversity of EPR schemes currently in place, producers tend to favor collective over individual

[60] Mauricio Ramos, Interview with M. Ramos.

[61] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

schemes" as the former offer economies of scale for waste collection and recycling.[62]"

2. These producers will pay for the cost of this system in proportion of the waste they create. The cost of aluminum recovery is not the same as the cost of plastic recovery, and nor are the prices offered by recycling plants for these materials the same. But this assumption is still valid because: i) the cost of recovery (such as transportation costs), and prices paid by recycling/ valorization plants are based on weight, and most importantly, ii) the weights of the different products' waste are known. It is possible that one type of packaging waste might contribute more on revenues or costs than another, but for the purpose of this exercise, we can assume the excesses produced by one might offset the losses produced by another, and contribute to the overall functioning of the nonprofit
3. Although it should not be, plastic is sometimes sent for incineration or to waste-to-energy plants. In our model we are going to assume that this will not happen.
4. Average curbside bottle bale yield is 38%. That is, of all the material collected from delivery points, only 62% is fit to recover and the rest goes to landfill[63]. (The yield loss occurs because other kinds of plastics used on the labels, caps of bottles; moisture in the bottles; and because some of the waste is not PET to

[62] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".
[62] E. Watkins et al., "EPR in the EU Plastics Strategy and the Circular Economy: A Focus on Plastic Packaging" (Institute for European Environmental Policy, 2017), https://ieep.eu/uploads/articles/attachments/95369718-a733-473b-aa6b-153c1341f581/EPR%20and%20plastics%20report%20IEEP%209%20Nov%202017%20final.pdf?v=63677462324.
[63] Closed Loop Partners, "Cleaning the RPET Stream: How We Scale Post-Consumer Recycled PET in the US" (Closed Loop Partners, n.d.), http://www.closedlooppartners.com/wp-content/uploads/2017/11/CLP-RPET-Report_Public-FINAL2.pdf.

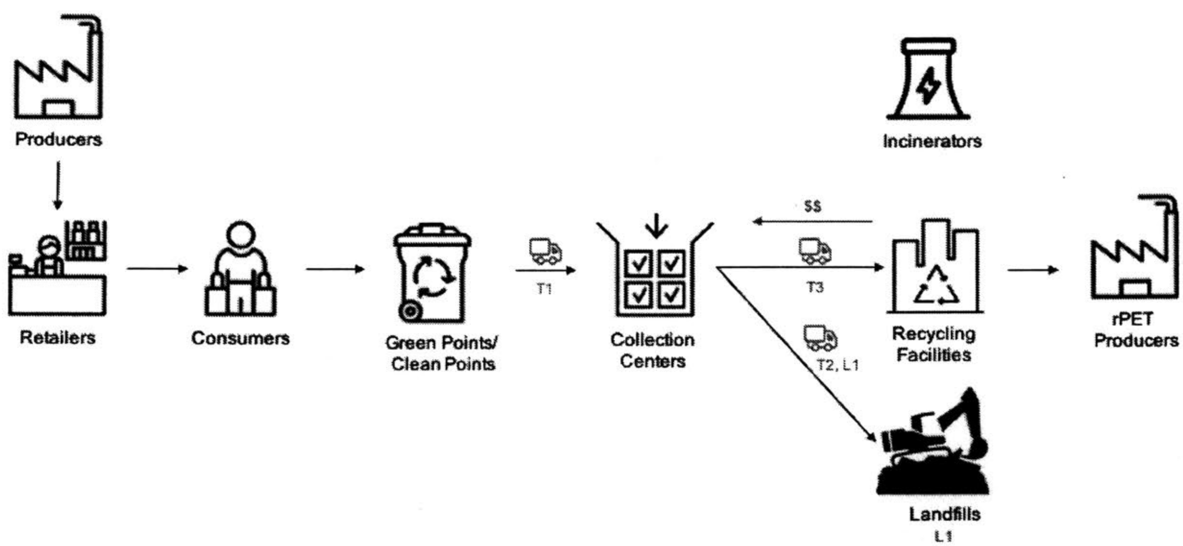
begin with). Therefore, in order to recycle 13% of all PET waste (which is the goal for the first year of EPR implementation, according to the MMA report), producers would have to aim to collect about 20.96% or about 21% of PET waste at the delivery points. (62% of 21% of the total is about 13% of total weight).

5. Average yield from door-to-door collection is 80%. We assume higher yield than from delivery points, because of the presence of a collector who could turn down collection of non-recoverable PET bottles. That means, in order to recover an additional 20%, the door-to-door collection would have to collect 25%, as 80% of 25% is 20%.

2.3 Costs for implementing the EPR Implementation System

2.3.1 Scenario 1

This diagram presents the material and economic flows in this scenario:



Total PET Packaging in 2019, in tons	78,867
PET Recycled (using 13% as recycled rate), in tons	10,609
Assuming 38% loss from delivery points, PET collected from delivery points, in tons	17,111.91

PET sent to Landfill from CA/ after collection from PV, PLs, in tons	6,502.53
Balance unrecovered PET, in tons	61,755
All packaging waste in 2019, in tons	1,878,102
Share of PET in all packaging in 2019	4%

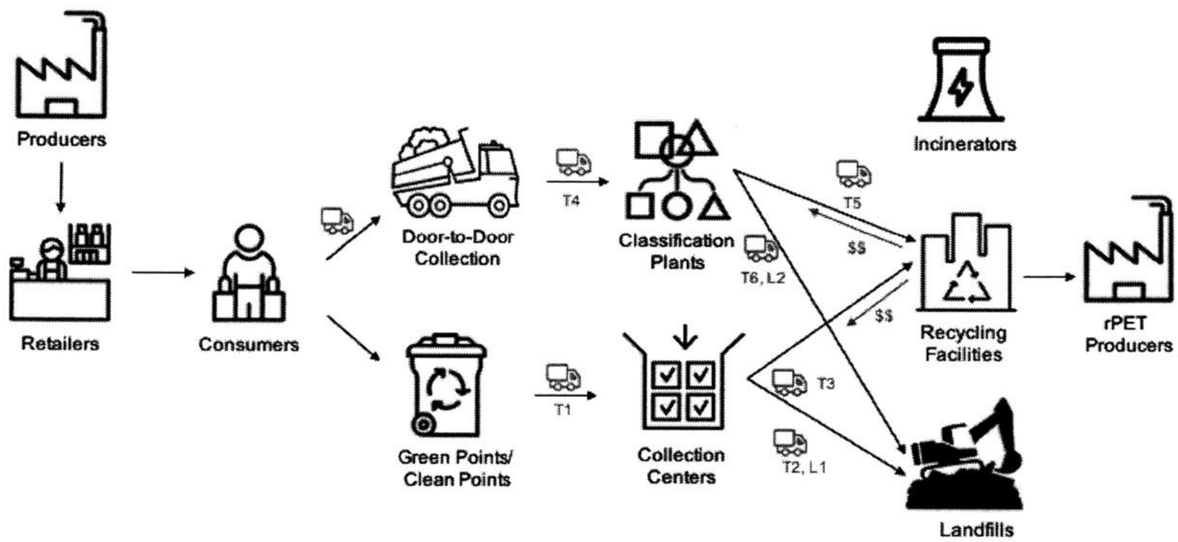
Costs for Clean Points (PLs), Green Points (PVs)	
Per ton processing cost for PET at PL, PV (CLP/ton)	165,240
Processing expense for all PET waste at PL, PVs, in CLP	2,827,572,561
Capital and maintenance expense (Capex)/ PV, in CLP	1,629,162
Total number of New PVs in 2019	3,600
Total Capex for New PVs in 2019, in CLP	5,864,983,224
PET producer's share of CAPEX (4% of total), in CLP	246,287,602
Capital and maintenance expense (Capex)/ PL, in CLP	4,907,343
Total number of New PLs in 2019	87
Total Capex for New PLs in 2019, in CLP	426,938,842
PET producer's share of CAPEX (4% of total), in CLP	17,928,396
Transport from PV, PL to CA, T1	Freight type: Short
Cost of transport, in CLP/ton	73,792.43
Amount of PET to be transported, in tons	17,112
Cost of T1, in CLP	1,262,729,765.74
Collection Center (CA) Costs	
Opex, Capex for Collection Centers, in CLP/ton	30,279
Amount of PET processed by CAs, in tons (from PL, PV)	17,112
Total Costs for CA for PET producers, in CLP	518,140,114
Transport from CA to Landfill, T2	Freight type: Short
Cost of transport, in CLP/ton	73792.43193

Amount of PET to be transported, in tons	6,503
Cost of T2, in CLP	479,837,310.98
Landfilling Fees, L1	
Landfill Tipping fee, CLP/ton	16305.93
Cost of Tipping, in CLP	106,029,757
Transport from CA to Recyclers, T3	Freight Type: Long
Cost of transport, in CLP/ton	147584.86
Amount of PET to be transported, in tons	10,609
Cost of T3	1,565,784,909.52
Administrative Costs for PRO, 2019, in CLP	336,810,000
PET Producers' Share of ADM costs (4% by weight), in CLP	13,472,400
Cost of the system for PET producers, excluding education & marketing (COM)	7,037,782,816
PET Producers' Share of COM costs (5% of the cost of the system), in CLP	370,409,621.89
Total Costs for PET Producers in Scenario 1	7,408,192,438
Revenue from Recycling Plants	
Price paid for PET bales by Recycling Plants(CLP/ton)	272,155.50
Amount sold to Recycling Plants (in tons)	10,609.39
Amount received from Recycling Plants	2,887,402,974.97
Profits/ Loss (Revenue-Costs), in CLP	-4,520,789,462.93
Number of PET bottles in 2019	7,154,688,406
Cost per bottle, in CLP	-0.63

2.3.2 Scenario 2

Scenario 2 is almost the same as above, except for an additional 20% recovery of PET through door-to-door collection. So the costs go up through this service, but as do the recovery and sale rates.

This diagram presents the material and economic flows in this scenario:



Total PET Packaging in 2019, in tons	78,867
PET Recovery from PV, PL (using 13% as recovery rate), in tons	10,609
Assuming 38% loss from delivery points, PET collected from PV, PL, in tons	17,111.91
PET sent to Landfill from CA/ after collection from PV, PLs, in tons	6,502.53
PET Recovered from Door-to-Door collection (20% of the recycled from PV, PL, in tons)	2,122
PET collected from Door-to-door (20% yield rate for recovery)	2,652.35
PET sent to Landfill from CP/ Door-to-door collection	530
Balance unrecovered PET, in tons	59,103
All packaging waste in 2019, in tons	1,878,102
Share of PET in all packaging in 2019	4%

Costs for Clean Points (PLs), Green Points (PVs)	
Per ton processing cost for PET at PL, PV (CLP/ton)	165,240
Processing expense for all PET waste at PL, PVs, in CLP	2,827,572,561
Capital and maintenance expense (Capex)/ PV, in CLP	1,629,162
Total number of New PVs with PET share in 2019	4162
Total Capex for New PVs in 2019, in CLP	6,780,572,272.22
PET producer's share of CAPEX (4%), in CLP	271,222,891
Capital and maintenance expense (Capex)/ PL, in CLP	4,907,343
Total number of New PLs in 2019	95
Total Capex for New PLs in 2019, in CLP	466,197,585.64
PET producer's share of CAPEX (4%), in CLP	18,647,903
Transport from PV, PL to CA, T1	Freight type: Short
Cost of transport, in CLP/ton	73,792
Amount of PET to be transported, in tons	17,112
Cost of T1	1,222,154,136
Collection Center (CA) Costs	
Opex, Capex for Collection Centers, in CLP/ton	30,279
Amount of PET being processed by CAs, in tons (from PV, PL)	17,112
Total Costs for CA for PET producers, in CLP	518,140,114
Transport from CA to Landfill, T2	Freight type: Short
Cost of transport, in CLP/ton	73,792
Amount of PET to be transported, in tons	6,503
Cost of T2	479,837,311
Landfilling Fees - from CA, L1	
Landfill Tipping fee, CLP/ton	16,306
Cost of Tipping, in CLP, L1	106,029,757

Transport from CA to Recyclers, T3	Transport Type: Long
Cost of transport, in CLP/ton	147,585
Amount of PET to be transported, in tons	10,609
Cost of T3	1,565,784,910
Transport from Door to Door to Classification Point, T4	Freight type: Urban
Cost of transport, in CLP/ton	49,195
Amount of PET to be transported, in tons	2,652
Cost of T4	130,482,076
Classification Point Costs	
Opex, Capex for Classification Points, in CLP/ton	191,614
Amount of PET being processed by CPs, in tons (the entire load from door to door)	2,652
Total Costs for CP for PET producers, in CLP	508,227,685
Transport from CP to Recyclers, T5	Freight type: Long
Cost of transport, in CLP/ton	147,585
Amount of PET to be transported, in tons	2,122
Cost of T5	313,156,982
Transport from CP to Landfill, T6	Freight type: Short
Cost of transport, in CLP/ton	73,792
Amount of PET to be transported, in tons	530.47
Cost of T6	39,144,623
Landfilling Fees - from CP, L2	
Landfill Tipping fee, CLP/ton	16,306
Cost of Tipping, in CLP, L2	8,649,796
Administrative Costs for PRO, 2019, in CLP	336,810,000
PET Producers' Share of ADM costs (4% by weight), in CLP	13,472,400
Cost of the system for PET producers, excluding education & marketing (COM)	8,022,523,144
PET Producers' Share of COM costs (5% of the cost of the system), in CLP	422,238,060.23

Total Costs for PET Producers in Scenario 2	8,444,761,205
Revenue from Recycling Plants	
Amount sold to Recycling Plants (in tons)	12,731.26
Price paid for PET bales by Recycling Plants(CLP/ton)	272,155.50
Amount received from Recyclers	3,464,883,570
Profits/ Loss (Revenue-Costs), in CLP	-4,979,877,635
Number of PET bottles in 2019	7,154,688,406
Cost per bottle of PET, in CLP	-0.70

Part III: Cost Analyses

3.1 Relative cost

In April-May 2018, the average cost of a 300 ml bottle of Coke or Pepsi in Santiago was 2018 was CLP 797.46, and the average cost of a 300 ml bottled water was CLP 627.14[64]. With a 3% inflation rate, we can expect the price to rise to CLP 821.38 and CLP 645.95 respectively in 2019. The cost of implementing a recovery system for PET bottles in Chile in 2019, CLP 0.63 in Scenario 1, and CLP .70 in Scenario 2, represent less than or 0.1% increase in the consumer-facing price of the average PET bottle. Demand for packaged drinks is inelastic,[65] so especially at this very marginal price increase, EPR implementation will not significantly affect the packaged beverage market or industry in Chile.

This finding is in line with our expectation that the cost of EPR requirements per PET bottle would be small. As a comparison, South African company PETCO, which represents the "PET plastic industry's joint effort to self-regulate post-consumer (PET)

[64] "'Cost of Living in Santiago,'" Numbeo.com, n.d., https://www.numbeo.com/cost-of-living/in/Santiago.
[65] Andrew Stevens, "Taxes on Bottled Water Are Better at Raising Money than Reducing Litter," *LSE US Center* (blog), December 6, 2016, http://blogs.lse.ac.uk/usappblog/2016/12/06/taxes-on-bottled-water-are-better-at-raising-money-than-reducing-litter/.

recycling," found that the cost of its model to the consumer is approximately 1 cent per bottle[66]. The May 2018 price of a Coke/Pepsi bottle in South Africa is approximately R12.20[67], and this cost of 1 cent represents .08% of the price of the bottle.

3.2 Zero-cost EPR?

Let's say we if we were a PET producer entering into the system, and we wanted to calculate how much PET we should be aiming to collect and then recycle in order to be cost neutral in this system.

Let's assume that today's cost of recycling are linearly related to the rate of recycling, and not that they rise in a non-linear, or another function, for higher rates of recycling.

Let's say the amount collected from door to door is X tons. We can set up a simple linear function to represent the costs.

Laying down the costs, as we know them from above

Costs of implementing EPR in Scenario 1	
Opex for PL, PV (CLP per ton)	165,239.99 * X
Capex PL (CLP)	17,928,396.27
Capex PV (CLP)	246,287,601.6
T1 (to CA, CLP per ton)	73,792.43 * X
Opex CA (CLP per ton)	30,279.49 * X
T2 (to Landfill, CLP per ton)	18,448.11 * 38% of X
L1 (at Landfill, CLP per ton)	4,076.48 * 38% of X
T3 (to Recycling, CLP per ton)	110,688.65 * 62%X
ADM (CLP)	13,472,400
COMS (CLP)	14,615,178.84 + (18,236.75* X)
Total costs (in CLP)	292,303,576.75 + (290,942.54 * X)

66 "Industry Projects," Pet.co.za, n.d., http://petco.co.za/petco-industry-projects/.

67 "'Cost of Living in South Africa,'" Numbeo.com, n.d., https://www.numbeo.com/cost-of-living/country_result.jsp.

Revenue from selling post-consumer PET bales to recyclers in Scenario 1	
Price x Quantity	CLP 272,155.50 * 62% of X
Revenue	168,736.41 * X

A PET producer's costs of implementing the EPR system are CLP 292,303,576.75 + 290,942.54 * X, and revenues are 168,736.41 * X. Clearly, no real (positive) value of X could make this system cost neutral for the system, as the price offered by the recycling facility for the PET bales is too low.

At what price would this system be cost neutral for the PET producers? Let's assume this is a price CLP Y. The equation we want to solve for is

Costs, CLP 292,303,576.75 + (290,942.54 * X) = Revenue, CLP Y* 62% of X

i.e. **Y = (292,303,576.75 + (290,942.54 * X))/ (62% * X), where 0< X < 78,867,** which is the total PET Packaging waste that we projected to be in Chile in 2019.

Similarly, for Scenario 2, let us assume PET producers collect X tons of post-consumer PET bottles from the system, which is the total of those collected from door-to-door and from delivery points (PL, PVs). The cost structure looks like this:

Costs of implementing EPR in Scenario 2	
Opex for PL, PV (CLP per ton)	17,111.91 * 87% of X
Capex PL (CLP)	18,647,903.43
Capex PV (CLP)	271,222,890.9
T1 (to CA, CLP per ton)	73,792.43 * 87% of X
Opex CA (CLP per ton)	30,279.49 * 87% of X
T2 (to Landfill, CLP per ton)	73,792.43 * 33% of X
L1 (at Landfill, CLP per ton)	16,305.93 * 33% of X
T3 (to Recycling, CLP per ton)	147,584.86 * 54% of X

T4 (Door-to-door collection to CP, CLP per ton)	49,194.95 * 13% of X
CP (Opex, capex for CP, CLP per ton)	147,584.86 * 13% of X
T5 (to recyclers, CLP per ton)	147,584.86 *11% of X
T6 (to landfill, CLP per ton)	73,792.43 *3% of X
L2 (at Landfill, CLP per ton)	16,305.93 *3% of X
Adm	13,472,400
COMS (all of above/19)	15,965,431.28 + 13,651.42 * X
Total	319,308,625.59 + (273,028.30 * X)

Revenue from selling post-consumer PET bales to recyclers in Scenario 2	
Price x Quantity	CLP 272,155.50 * 64% of X
Revenue	174,179.52 * X

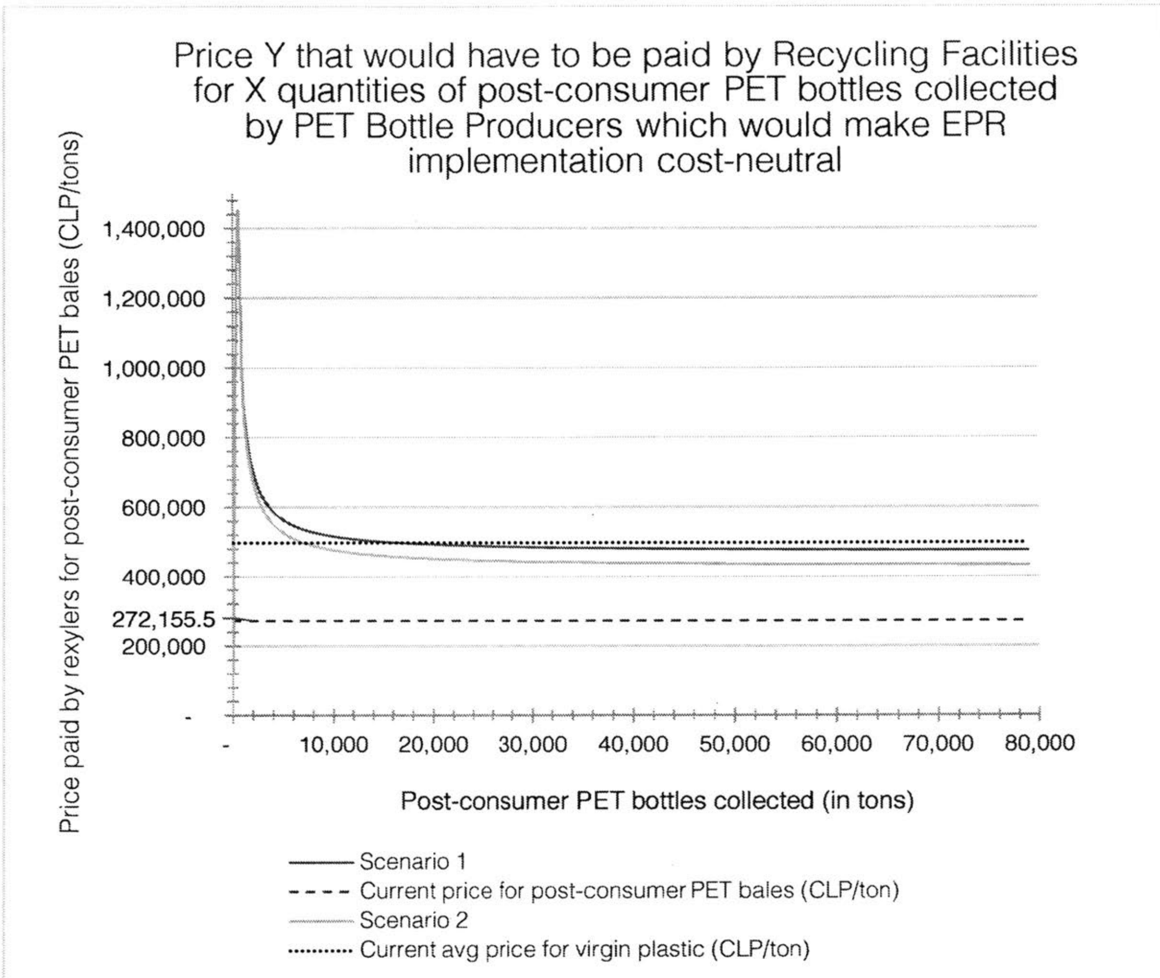
Once again, PET producer's costs of implementing the EPR system are CLP 319,308,625.59 + (273,028.30 * X), and revenues are 174,179.52 * X. Again, no real (positive) value of X could make this system cost neutral for the system, as the price offered by the recycling facility for the PET bales is too low to offset the costs of the system.

At what hypothetical price would this system be cost neutral for the PET producers? Let's assume this is a price CLP Y. The equation we want to solve for is

Costs, CLP 319,308,625.59 + (273,028.30 * X) = Revenue, CLP Y* 64% of X

i.e. **Y = (319,308,625.59 + (273,028.30 * X))/ (64% * X), where 0< X < 78,867**, which is the total PET Packaging waste that we projected to be in Chile in 2019.

The equations for both Scenario 1 and 2 graph as follows:



For Scenario 1, the average EPR Implementation cost-neutral price for post-consumer PET is **CPL 502,937.8/ ton,** which is 1.85 times, i.e. almost double of today's going rate for post-consumer PET bales, CPL 272,155.5 per ton.

For Scenario 2, the average EPR Implementation cost-neutral price for post-consumer PET is **CPL 462,241.8/ ton**, which is 1.7 times, i.e. almost double of 2019 expected price for post-consumer PET bales, at CPL 272,155.5 per ton.

Today the going price for virgin PET flakes, as seen online marketplaces, is about USD 750- USD 850/ ton, i.e., about CPL 466,350 – CPL 528,530, for an average price of CPL 497,350, also shown in the graph.

It is interesting to note that the rate of recycling has no effect on the cost-neutral price for EPR after about 10,000 tons, which is around the 13% recycling rate set for the first year of implementation. The only thing that can make EPR Zero-cost is a higher price paid for post-consumer PET bales.

It is estimated that the cost of converting post-consumer PET into flake is about USD 0.17/lb, and the cost of converting these flakes into pellets and sheets is about USD 0.10/lb[68], for a total processing cost of turning post-consumer PET bales to rPET to be USD 0.27/lb, or USD 540/ton, or CPL 335,772/ ton. For the recyclers, when you add their cost of post-consumer PET purchase (CPL 272,155.5 per ton), and the cost of processing it into rPET (CPL 335,772 per ton), we estimate the cost of rPET as CPL 607,927.5/ ton. At the same time, rPET is a substitute for virgin PET, and its buyers will buy the cheaper alternative.

The price that the producers would need to be paid for their collection of post-consumer PET bottles is almost the same as the going rate for virgin PET pellets today, which is what they pay to be able to produce these bottles in the first place. The economics here subtly reinforce the point that the value in PET packaging is not lost after first-use, and yet the system is not yet integrated or intelligent enough to capture this leaking value.

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[68] Closed Loop Partners, "Cleaning the RPET Stream: How We Scale Post-Consumer Recycled PET in the US".

Part IV: Discussion

4.1 Breaking the PETriarchy's Virgin Obsession

Over 90% of plastics produced are "virgin," i.e. derived from fossil fuels feed-stocks, which accounts for about 6% of global oil consumption, equivalent to the entire aviation sector's annual oil consumption[69]. According to the Ellen Macarthur Foundation, 95% of plastic packaging material value, or USD 80–120 billion annually, is lost to the global economy after a short first-use cycle[70]. In principle, almost all plastics used in packaging are recyclable with little or no quality impairment[71], and yet, less than 14% of plastic packaging worldwide is collected for recycling, and even lesser is actually recycled.

Before plastic can be recycled, it has to be collected, sorted, and cleaned/ processed. Plastic is sorted according to its resin, either through its resin identification code which is usually stamped on the bottom of the container (PET for example has the code of 1), or through its weight/density, and are also often separated by color. Sorting is a crucial step in recycling of plastic, as different plastics are made of different polymers with differing weights that can phase-separate and settle in layers when recycled. Collection, and sorting, with minimal processing alone can represent over 50% of all costs associated with recycling the plastic[72].

Plastic recycling can be classified in two ways, based on post-recycling application, or on the process used to recycle the plastic. Post-recycling application of plastics classifies it as either closed-loop or open-loop. In open-loop recycling, a product is

[69] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics".
[70] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics".
[71] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics".
[72] Closed Loop Partners, "Cleaning the RPET Stream: How We Scale Post-Consumer Recycled PET in the US".

converted to other types of products, usually associated with a lower value (also called cascaded recycling). In closed-loop recycling, a product is recycled back into the same, or similar, or closely associated, products. Closed-loop recycling is considered one of the most sustainable options in plastic waste management, as it retains most of the value of the material and the product[73].

Plastic can be recycled through mechanical operations (grinding, washing, separating, drying, re-granulating and compounding), or through chemical processes that break down the plastic polymers into individual monomers that can then re-polymerized to produce plastic again. Some chemical recycling processes can upcycle post-consumer plastics into virgin-quality polymers, but currently these technologies are not very widespread, or economically viable.

As rPET's material is decoupled from fossil fuels, its production emits 90% lesser carbon dioxide than virgin PET's production does. Its processing also uses 70% lesser energy than virgin PET's production does (see table below). Substituting virgin PET by rPET is not only better for reducing our land-and ocean-filling, but also because it reduces our carbon footprint and greenhouse gases emissions significantly.

Resin Type	Energy in processing	CO_2 emissions in processing
Virgin PET	80 GJ/ton	2,540 kg/ton
rPET	24 GJ/ton (70% lower)	180 kg/ton (93% lower)[74]

[73] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics".
[74] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes".

Unsurprisingly, the price of virgin plastic is very closely related to the price of oil, and because rPET is essentially a substitute product, its price is at parity with the price of virgin PET. Both virgin and recycled plastic prices have been volatile and declined for many plastic types between 2012 and 2015 when oil prices dropped. This was especially true for PET, when the price of rPET dropped by 30%-40%[75]. All three, oil, virgin PET, and rPET prices have slowly climbed up since then. But the price of rPET is often at a discount, because the cost of producing rPET is likely to be over USD 0.13/lb higher than producing virgin PET, i.e. about USD 260/ton more[76].

When reduce and reuse are not available, recycling is the most sustainable option. But the PET reverse chain (collection, sorting, and transportation), its high purchase price[77], and the availability of markets for rPET[78], pose serious challenge to rPET manufacturers[79]."

Packaged beverage producers could affect these dynamics significantly, and under EPR, they are motivated to do so. As we have already seen above, they would like to be paid more for their collected post-consumer PET bales, but the price that PET recyclers can pay for those is affected by the demand for rPET, as well as by the price

[75] Ellen Macarthur Foundation, "The New Plastics Economy – Catalyzing Action.

[76] Closed Loop Partners, "Cleaning the RPET Stream: How We Scale Post-Consumer Recycled PET in the US".

[77] Frank Welle, "Twenty Years of PET Bottle to Bottle Recycling—An Overview," *Resources, Conservation and Recycling* 55, no. 11 (September 2011): 865–75.

[78] T.M. Coelho, R. Castro, and J.A. Jr. Gobbo, "PET Containers in Brazil: Opportunities and Challenges of a Logistics Model for Post-Consumer Waste Recycling," *Resources, Conservation and Recycling* 55, no. 3 (January 2011): 291–99.

[79] Thomas Lindhqvist, "Extended Producer Responsibility in Cleaner Production: Policy Principle to Promote Environmental Improvements of Product Systems" (IIIEE, Lund University, n.d.), https://lup.lub.lu.se/search/ws/files/4433708/1002025.pdf.

of virgin PET. If beverage producers increase the demand for rPET by using more rPET and less virgin plastic in their bottles, they could allow for the price of rPET to rise. But as long as virgin plastic remains untaxed and low, this will remain a challenge. Luckily, virgin plastic's price is dependent on oil prices, which have been rising since falling to their lowest price in the last 15 years, in January 2016[80]. This strategy would win PET beverage producers some freedom from the volatility of crude oil prices that determine the price for their most expensive raw material[81].

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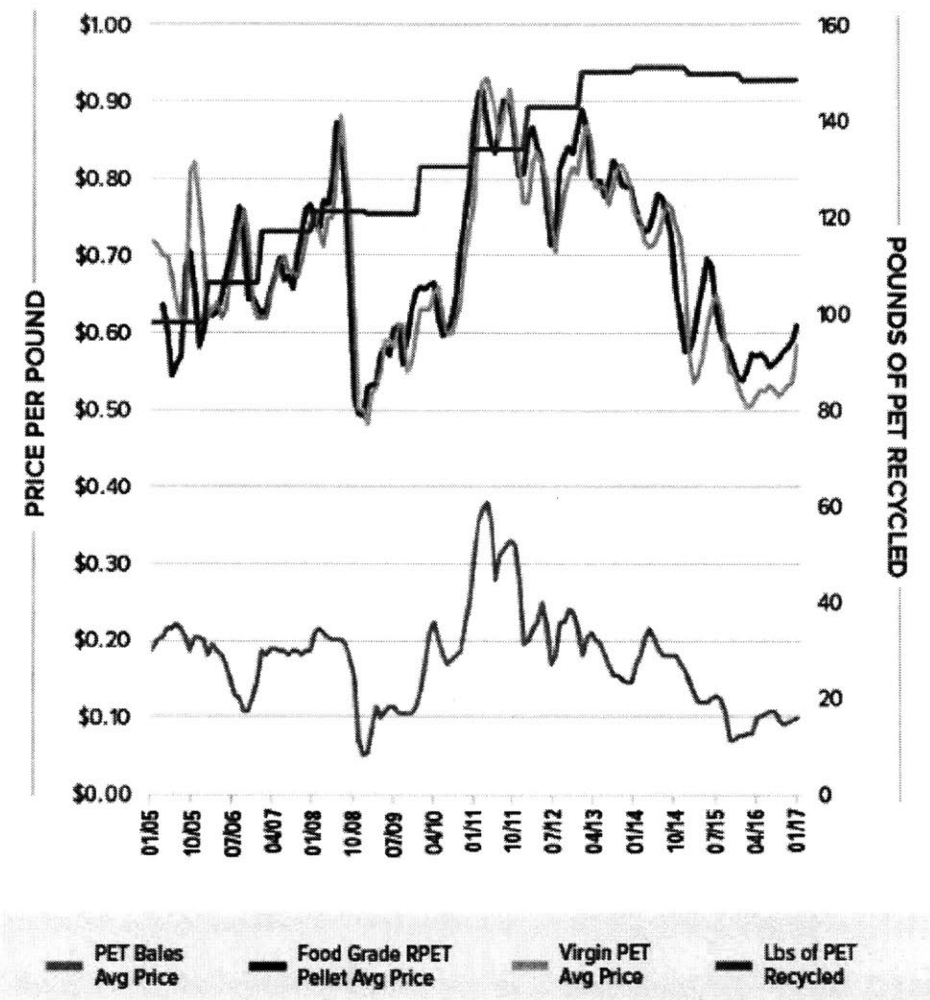
[80] "Crude Oil Prices - 70 Year Historical Chart," Macrotrends, n.d., http://www.macrotrends.net/1369/crude-o il-price-history-chart.

[81] Plastic is the most expensive raw material in a water bottles, and also for the most popular format (300ml) of carbonated soft drink. Own calculations, using standard prices for water, plastic, sugar.



[82]

Clearly, the negative externality of carbon emissions is a market failure and should be incorporated in the system. The cost difference between rPET and virgin PET, and the table above make a very strong case for carbon taxes on virgin plastic.

Virgin PET emits ~2.6 tons of CO_2 emissions (tCO_2e) more than rPET does, and rPET is about USD 260/ton more expensive to produce than virgin PET is (from the section

[82] "Data Corner: The Challenging Economics of RPET," Resource Recycling, February 26, 2018, https://resource-recycling.com/recycling/2018/02/26/data-corner-challenging-economics-rpet/.

above). A carbon tax of USD 100/ tCO_2e would allow rPET producers to compete on a more equal footing with virgin PET producers. And in fact, analyses on carbon pricing have indicated a global average carbon price of between US$80/$tCO_2e$ and US$120/$tCO_2e$ would be consistent with the goal of limiting temperature rise to under 2°C[83], although in practice, 85% of those economies that do enforce a carbon price do so at a price of USD10/tCO_2e[84].

A modest carbon tax on virgin PET plastic is not completely out of context in Chile. In 2014, again under President Bachelet, Chile became the first South American country to tax carbon. The law primarily targets large energy producers, and it prices carbon at only USD 5/ tCO_2e[85]. It is supposed to come into effect in 2018.

4.2 "Valorizing" Recycling?

Unlike metals like Aluminum which can be recycled infinitely, traditional recycling degrades the plastic, which means after its first-use, plastic is recycled into lower-value applications, often representing their final use.

In the case of PET, rPET, it is most commonly converted to fiber (~40%), and finds itself into products such as carpets, blankets, clothing and other textiles. Globally, only 28% of PET produced is recycled, and only about 20% of that, or 6% of the total turns back

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[83] L. Clarke et al., "'Assessing Transformation Pathways,' in Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" (Cambridge University Press, 2014).

[84] A. Kossoy et al., "State and Trends of Carbon Pricing 2015" (Washington, DC: World Bank Group, September 2015), http://documents.worldbank.org/curated/en/636161467995665933/pdf/99533-REVISED-PUB-P153405-Box393205B.pdf.

[85] Reuters Staff, "Chile Becomes the First South American Country to Tax Carbon," *Reuters*, September 26, 2014, https://uk.reuters.com/article/carbon-chile-tax-idUKL6N0RR4V720140927.

in rPET bottles in closed-loop recycling[86]. Other common end-use products are sheet and films, and strapping tape.

In most cases, closed-loop mechanical recycling (bottle-to-bottle) would be more energy and material efficient than open-loop mechanical recycling (bottle-to-fiber), followed by chemical recycling. But after closed-loop mechanical recycling, the rPET bottle will likely not be recycled back into another bottle, because rPET recycling is not widespread, and/or the economics are not viable enough for it to be so.

Of course, the more efficient solution for PET beverage producers would be to close the loop themselves. That is, instead of selling their post-consumer PET bottles to recyclers at a loss, and then buying rPET from them for the same price they pay virgin producers, they could instead process their collected and sorted bottles into recycled plastic to use as raw material themselves. And this seems to be happening, especially in those places where EPR exists. In 2014, bottle-to-bottle use finally surpassed textiles to became the main end market for rPET in Europe. The average recycled content in PET bottles in Europe is currently around 12%, which is much higher the global average of about 3% (European PET Bottle Platform, 2017)."[87] While there probably are other complementary legal and economic frameworks that are enabling this, EPR has is probably also having the effect of integrating the producers' downstream and upstream value chains.

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[86] Closed Loop Partners, "Cleaning the RPET Stream: How We Scale Post-Consumer Recycled PET in the US".

[87] E. Watkins et al., "EPR in the EU Plastics Strategy and the Circular Economy: A Focus on Plastic Packaging" (Institute for European Environmental Policy, 2017), https://ieep.eu/uploads/articles/attachments/95369718-a733-473b-aa6b-153c1341f581/EPR%20and%20plastics%20report%20IEEP%209%20Nov%202017%20final.pdf?v=63677462324.

But even if, or more likely when, it becomes financially lucrative for PET producers, recycling plastic is not a complete solution. The currently widespread recycling technologies degrade the resin which eventually makes its way into low-value products. In open-loop cascading recycling, high-value plastic such as PET would at best eventually finds itself in products such as park benches made from recycled plastic. Recycling is of course more sustainable, but it is not a true long-term solution to the land-, or ocean-filling plastic problem.

As long as our virgin plastic production is still increasing, and the world does not have an infinite capacity for park benches, which too will need to be disposed off, we will continue to bear the guilt of bequeathing a burden. The lifespan of a plastic bottle is estimated between 400-500 years; for Styrofoam, often used for take-away hot beverages, the lifespan is estimated to be over 5,000 years. Recycling those only reduces and/or delays land-/ocean-filling by one production and use cycle, which might be short, in the case of a plastic bottle, or long, in the case of a park-bench. The only long-term sustainable solution is to eliminate plastic application from products or systems where it is not needed.

4.3 Opportunities to Reduce or Eliminate Waste

4.3.1 Water, water everywhere

Changing consumer preferences for healthier options has caused Carbonated Soft Drinks' volumes to shrink year on year for over thirteen years straight. As diet and other soda lose volumes, bottled water and other health drinks have been gaining share at an accelerating pace. In fact, bottled water became the largest beverage category sold by volume in United States in 2016[88], and it will likely continue to be sold more than soda in the future.

Water is increasingly being commoditized, and one does not even have to reference Marx for this argument to be presented as fact. The proof of it is the presence of various indexes to track water-related investment opportunities: Dow-Jones U.S. Water Index, ISE-B&D Water Index, S&P 1500 Water Utilities Index, S&P Global Water Index; Bloomberg World Water Index, MSCI World Water Index to name a few.

With rising incomes, urbanism, consumerism, and awareness around water safety, PET bottle consumption has been surging, especially in China, and swelling global plastic demand. Bottled water brought in over USD 200 billion in revenues in 2017, and has been growing at more than 9% per annum. The market is expected to grow to USD 350 billion by 2021[89]. Asia-Pacific is its largest consumer, which is hardly a surprise given it has some of the most populous countries of the world, which have poor public infrastructure.

Bottled water compounds the large negative externalities of two commodities, plastic and privatized water. Over a million plastic bottles are bought around the world every minute—20,000 bottles a second—and the number is expected to rise by another 20% by 2021. Whatever our environment stood to gain from people drinking less soda, it has already lost more to our thirst for bottled water.

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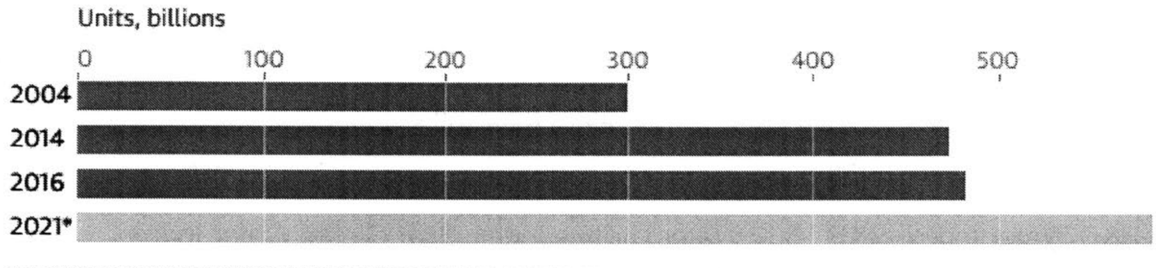
[88] "Americans Are Now Drinking More Bottled Water Than Soda," Fortune, March 10, 2017, http://fortune.com/2017/03/10/soda-tax-bottled-water-americans/.

[89] "The Global Bottled Water Market: Expert Insights & Statistics," *Market Research Blog* (blog), February 28, 2018, https://blog.marketresearch.com/the-global-bottled-water-market-expert-insights-statistics.

Global PET plastic bottle production



Guardian graphic | Source: Euromonitor. * forecast

Some local governments and institutions are recognizing that water is perhaps one such "product" which might not need to be commoditized in plastic bottles. In response to a bottling company that wished to sell the groundwater from its aquifer, the Australian town of Bundanoon became the first town in the world that voted to ban the sale of bottled water in 2009. Since then, over 100 cities in the United States have adopted measures to restrict government spending on bottled water, including, most notably for its scale and influence, San Francisco[90]. Between 2011 and 2017, 23 US national parks enforced a ban on the sale of bottled water. This prevented 2 million plastic bottles from being discarded each year until September 2017, when the Trump Administration reversed the ban[91].

But a ban on bottled water can and should only be enforced where people have easy access to free and safe drinking water, and where they perceive it to be safe. Consumer are more likely to use bottled water as their primary drinking water source when they

[90] Sam Levin, "How San Francisco Is Leading the Way out of Bottled Water Culture," *The Guardian*, June 28, 2017, https://www.theguardian.com/environment/2017/jun/28/how-san-francisco-is-leading-the-way-out-of-bottled-water-culture.

[91] Jessica Glenza, "National Park Ban Saved 2m Plastic Bottles – and Still Trump Reversed It," September 26, 2017, https://www.theguardian.com/environment/2017/sep/26/national-park-plastics-bottled-water-ban.

perceive that drinking water is not safe, and those who give lower ratings to the quality of their ground water are more likely to regularly purchase bottle water for drinking and use it as their primary drinking water source[92].

In April 2018, the city of Flint, Michigan, announced it will no longer be providing its residents free bottled water, which it had been doing in the aftermath of the Flint Water Crisis since January 2016. The tragedies that Flint's lead-contaminated water wielded are not forgotten, and not yet trusting their water to be safe, residents queued up at the distribution points on the last days of the free bottle provision[93]. It is hard to estimate how many millions of bottles would have been distributed in these two years, but as the city dealt with one crisis, it also contributed to another invisible one. A less-waste solution would have been to provide bottled-water quality or branded water as a service delivered to its citizens in tankers. Such solutions are common in cities around the developing world when they face a water shortage.

Unlike in most countries, in Chile water is privatized. Privatization of water rights came into effect under General Pinochet, and have stayed the course in subsequent political cycles. It is often touted as a success story for free-market water systems for its high coverage of drinking water and sanitation under nearly full privatization. But Chile also faces unique challenges in its water systems. Majority of its water supply is localized in the southern Patagonia region, and its largest urban center Santiago is in the center of the longest country of the world. More critically, Chile's most important industry, copper

[92] Hu Zhihua, Lois Wright Morton, and Robert L. Mahler, "Bottled Water: United States Consumers and Their Perceptions of Water Quality," *International Journal of Environmenta Research and Public Health*, February 21, 2011, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3084479/.

[93] Jacey Fortin, "Michigan Will No Longer Provide Free Bottled Water to Flint," *The New York Times*, April 8, 2018, https://www.nytimes.com/2018/04/08/us/flint-water-bottles.html.

mining, is primarily located in the Atacama Desert in the north, and is the second largest consumer of water after agriculture in the country. Sometimes called the "driest place in the world," the region's water availability is on par with that of many Middle Eastern countries[94].

As water use rights are private in Chile, Chile's citizens are in competition for the supply of water with other consumers, including its water-intensive mining sector. Chileans' unique position in not having water as a public resource came to the forefront with recent protests in Santiago, whose 7.2 million citizens pay one of highest tariffs for water in Latin America[95].

Currently the country's private urban water suppliers are not in the business of packaged water. They can be thought of in competition with bottled water producers. (It is recognized that the price differential—bottled water is almost 1800 times as expensive as tap water—is so large that this not a typically competitive scenario[96]). Should they decide to enter the lucrative and growing market, they would have a unique position of owning Chileans' water supply at home and also being a player in the market, and be able to affect bottled water consumption through supply and price modulation. In an interesting turn, by banning or regulating bottled water, Chile would actually increase market power for the private urban water suppliers as their

[94] "In Chile, a Private Solution for a Public Good," Stratfor Worldview, January 20, 2017, https://worldview.stratfor.com/article/chile-private-solution-public-good.

[95] Daniel Gallagher, "The Heavy Price of Santiago's Privatised Water," *The Guardian*, September 15, 2016, https://www.theguardian.com/sustainable-business/2016/sep/15/chile-santiago-water-supply-drought-climate-change-privatisation-neo liberalism-human-right.

[96] Daniel Gallagher, Interview with Daniel Gallagher on Water Prices in Chile, May 7, 2018: Aguas Andinas in Santiago charges CLP 357,69CLP per cubic meter.
(Own calculations: 1 Liter tap water liter= USD 0.00057; 1 Liter bottled water is roughly sold for USD 1 in Santiago.)

"competition" in bottled water would be eliminated. But in doing so, the Chilean government would be protecting its environment from the blight of plastic bottles.

4.3.2 New-old consumption models

Plastic bottles replaced glass bottles for beverages primarily because of their light weight and extreme durability, but as we contend with the enduring and growing weight of environmental contamination caused by plastic, we might need to reconsider other models such as filling stations or delivery instead of use-and-throw products. Of course consumer behavior and habits would have to be changed in order to make this viable for producers, but the externalities of their products have to be incorporated in some way.

There is precedent for this. The single-use plastic bag has been phased-out or banned in over 50 local, city, state, or national governments by 2018[97], and consumers are learning to carry their own bags with them when they go shopping. In the same way, consumers can make a habit out of carrying their own bottles, or buy them, at shops that have filling stations to buy beverages of their choices.

4.4 The other hidden factor: waste-pickers and waste management

4.4.1 Background

Waste picking is a significant informal sector economic activity carried out by poor and often marginalized social groups in many urban areas of low income countries. By one estimation, 2% of the population in Asian and Latin American cities depend on waste

[97] Dirk Xanthos and Tony R. Walker, "International Policies to Reduce Plastic Marine Pollution from Single-Use Plastics (Plastic Bags and Microbeads): A Review," *Marine Pollution Bulletin* 118, no. 1–2 (May 15, 2017): 17–26.

picking for their livelihood[98]. Globally, the informal waste picking sector represents about 20 million people[99].

The informal waste picking sector, made up of "individuals or enterprises who are involved in waste management activities, but whose activities are neither organized, sponsored, financed, contracted, recognized, managed, taxed nor reported upon by the formal waste authorities[100]." The sector contributes to waste management in two broad ways:

i) the extraction and removal of waste, which includes
    a. removal of recyclables and re-usable materials from mixed waste[101], from streets or public spaces, or extracted from communal bins, or from (often illegal) dumps, or landfills;
    b. Itinerant Waste Buyers (IWBs) who buy (or barter) specific recyclable materials from door to door (such as "kabadiwalas" in South Asia)

ii) and the informal valorization sector, which consists of:
    a. individuals, co-operatives, families and micro-enterprises that function as an extractive resource industry[102]

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98 David C. Wilson, Costas Velis, and Chris Cheeseman, "Role of Informal Sector Recycling in Waste Management in Developing Countries," *Habitat International* 30, no. 4 (n.d.): 797–808.

99 Joyce Ojino, "EPR as a Mechanism for Integrating the Informal Sector An Evaluation of Post-Consumer PET Waste Management in South Africa" (IIIEE, Lund University, 2016), http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8893313&fileOId=8893318.

100 Anne Scheinberg, Michael H. Simpson, and Yaminiet Gupt, "The Economics of the Informal Sector in Solid Waste Management," *CWG Publication Series No.5*, 2010, https://www.giz.de/en/downloads/giz2011-cwg-booklet-economicaspects.pdf.

101 Wilson, Velis, and Cheeseman, "Role of Informal Sector Recycling in Waste Management in Developing Countries".

102 Scheinberg, Simpson, and Gupt, "The Economics of the Informal Sector in Solid Waste Management".

Worldwide, there is generally a limited social acceptance or even explicit discrimination against informal sector activities, especially around waste picking. In the Indian subcontinent, for example, waste picking has an archaic deep-rooted association with the caste system. A telling example is that in some cities, nearly all waste pickers are from the "untouchable" caste[103], and, many cities view them as a social problem and public nuisance[104]. People perceive them to introduce crime into neighborhoods[105]. Furthermore, even without embedded cultural norms, lack of data on the economic value of informal sector activities makes it difficult for the sectors' contribution to be understood and appreciated[106].

In Chile, the informal waste pickers are called "cartoneros," "cachucheros" or, "recolectores," and, in legalese, "reciclador de base." By the very nature of their work being in the informal sector, their economic contribution is difficult to concretely quantify. A study in 2005 estimated that in the the Greater Santiago region, the so-called base recyclers collected about 70% of the total recycled garbage, and up to 10% of the total solid waste, preventing the landfilling of 810 tons of garbage everyday[107], which is a

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[103] Poornima Chikarmane, "Integrating Waste Pickers into Municipal Solid Waste Management in Pune, India," WIEGO Policy Brief (Urban Policies) No 8 (WIEGO (Women in Informal Employment: Globalizing and Organizing), n.d.), http://www.wiego.org/sites/wiego.org/files/publications/files/Chikarmane_WIEGO_PB8.pdf.

[104] O.O. Oguntoyinbo, "Informal Waste Management System in Nigeria and Barriers to an Inclusive Modern Waste Management System: A Review," *Public Health* 126, no. 5 (May 2012): 441–47.

[105] L. Godfrey, W. Strydom, and R. Phukubye, "Integrating the Informal Sector into the South African Waste and Recycling Economy in the Context of Extended Producer Responsibility," *CSIR*, n.d.

[106] O.O. Oguntoyinbo, "Informal Waste Management System in Nigeria and Barriers to an Inclusive Modern Waste Management System: A Review,"

[107] "Sistemas de Reciclaje: Estudio de Casos En La Región Metropolitana" (Corporación Nacional de Medio Ambiente (CONAMA), 2005).

sizable contribution. They make their income from the sale of recyclable materials to material recuperation companies, intermediaries, and recycling centers.

Although there are no official figures available, it is estimated that there are around 60,000 base recyclers in the country, and about 180,000 people living from this activity[108]. About 3,500 (5%) are organized into collective or localized groups[109]. A 2016 study interviewed several waste picking collectives, and 84% of the interviewees declared their main reason waste picking was a "complex economic situation,[110]" which the author describes as conditions of poverty, the low level of qualification, absence of opportunities of employment[111], low levels of training in trades, low levels of education, and from these, low levels of employability[112].

Most waste pickers in Chile depend on intermediaries of different sizes to deliver their waste to valorizing enterprises. It was estimated that two-thirds of the materials collected are sold to intermediaries, or to large formal recycling companies, where it is

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[108] "Política de Inclusión de Los Recicladores de Base 2016-2020" (n.d.), http://portal.mma.gob.cl/wp-content/uploads/2016/12/Politica-de-inclusion-de-recicladores-de-base.pdf.

[109] "Law Report: Chile Waste Pickers in Chile," Global Alliance of Waste Pickers, n.d., http://globalrec.org/law-report/chile/.

[110] Pablo Navarrete-Hernández, "De Cartoneros a Recicladores Urbanos. El Rol de Las Políticas Locales En Mejorarla Sustentabilidad de Los Recolectores de Base," *Investigaciones Regionales – Journal of Regional Research*, no. 35 (2016): 83–106.

[111] Pablo Javier Navarrete-Hernández, "Scavenging Revisited: Supporting Scavengers in Santiago de Chile," in *The Ideal City: Between Myth and Reality. Representations, Policies, Contradictions and Challenges for Tomorrow's Urban Life"* (RC21 International Conference, Urbino, Italy, 2015), http://www.rc21.org/en/wp-content/uploads/2014/12/A3.1_Navarrete.pdf.

[112] Pablo Navarrete-Hernández, "De Cartoneros a Recicladores Urbanos. El Rol de Las Políticas Locales En Mejorarla Sustentabilidad de Los Recolectores de Base".

transformed into raw material for the local industries, and the remaining third is sold in informal street markets with no connection to the formal economy[113].

Moreover, this profession is not a temporary or economically insignificant condition. The average waste picker had been involved in this work for 12 years, and 86% of the interviewees indicated that recycling had been their main economic activity for more than four years. Indeed, the majority feel satisfied with the activity (84%), and even consider themselves micro-entrepreneurs (80%), and would continue their current activity, even if they were offered a formal job[114]. However, their incomes are not stable, varying with the fluctuating prices offered for waste in the recycling market[115].

From another study in 2010, we learn that 66% of the informal recyclers earned 50% or more of the average individual household income in the Greater Santiago region[116]. Which, coupled with the lack of access to other employment, could explain why so many of them are satisfied with the activity. Indeed, those earning higher income from their recycling activities even consider themselves "micro-entrepreneurs"[117].

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[113] Pablo Navarrete-Hernández, "De Cartoneros a Recicladores Urbanos. El Rol de Las Políticas Locales En Mejorarla Sustentabilidad de Los Recolectores de Base".
[114] Pablo Navarrete-Hernández, "De Cartoneros a Recicladores Urbanos. El Rol de Las Políticas Locales En Mejorarla Sustentabilidad de Los Recolectores de Base".
[115] "Política de Inclusión de Los Recicladores de Base 2016-2020".
[116] Tahnee María González Martínez, "Analysis of Different Municipal Solid Waste Management Systems in Santiago de Chile" (Stuttgart University, 2011), https://elib.uni-stuttgart.de/bitstream/11682/1926/1/Dissertation_Tahnee_Gonzalez_Martinez_Print2.pdf.
[117] Pablo Navarrete-Hernández, "De Cartoneros a Recicladores Urbanos. El Rol de Las Políticas Locales En Mejorarla Sustentabilidad de Los Recolectores de Base".

4.4.2 Formalizing the informal: policy's effect on base recyclers

What happens when a largely opaque and significant informal industry is formalized with the passing of regulations such as EPR? The OECD postured that the presence of the informal sector poses a major challenge to EPR initiatives in non-OECD countries[118].

This is because, unless carefully integrated, the informal sector might compete with formal authorities for materials, or may be in violation of set regulations[119]. As postured by Joyce Ojino in their dissertation, the informal sector could divert waste materials covered by EPR schemes into informal channels. And, if it persists, its failure to comply with health, safety and environmental standards may make the informal sector's operations cheaper than those of official recyclers which, may undermine the operations of EPR schemes[120].

For example, in Bulgaria, the informal sector was neither consulted nor legally provisioned for in the development of a mandatory EPR system for packaging waste. The informal sector continued to capture 90% of materials from households and businesses that did not switch from their preferred recycling channels, and the EPR system only captured the remaining 10%, leading to its ultimate failure[121].

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118 "Extended Producer Responsibility- Updated Guidance" (OECD, 2015), http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/EPOC/WPRPW(2015)16/FINAL&docLanguage=En.

119 Scheinberg, Simpson, and Gupt, "The Economics of the Informal Sector in Solid Waste Management".

120 Joyce Ojino, "EPR as a Mechanism for Integrating the Informal Sector An Evaluation of Post-Consumer PET Waste Management in South Africa" (IIIEE, Lund University, 2016), http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8893313&fileOId=8893318.

121 "Extended Producer Responsibility- Updated Guidance" (OECD, 2015).

Regulating a waste management system without incorporating the informal sector might hurt cost efficiency of cities as the informal sector reduces collection, transport and disposal costs for municipalities[122]. It would also be a lost opportunity: the informal sector might increase valorization levels of waste[123]. One study estimated that integration of the informal sector could lead to 78% in savings, and to about 80% avoidance of landfill cost[124].

A study did a comparative analyses of the effect of local policy on the performance of grassroots recyclers in the greater Santiago area. It found that the level of policy support was positively associated with the level of economic development of the waste picking cooperatives across indicators of productivity, wages, quantity of materials delivered to local industry, and savings created for the municipality. It also found that supportive local policies promoted higher levels of income equity among their grassroots recyclers (Gini coefficient of 0.17)[125].

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[122] Sanjay K. Gupta, "Integrating the Informal Sector for Improved Waste Management" (Private Sector and Development., 2012), http://www.nswai.com/Waste_Portal2/Research_papers/pdf/rp_sept15/Integrating%20the%20informal%20sector%20for%20improved%20waste%20management.pdf.

[123] Scheinberg, Simpson, and Gupt, "The Economics of the Informal Sector in Solid Waste Management".

[124] O.O. Oguntoyinbo, "Informal Waste Management System in Nigeria and Barriers to an Inclusive Modern Waste Management System: A Review".

[125] Pablo Navarrete-Hernández, "De Cartoneros a Recicladores Urbanos. El Rol de Las Políticas Locales En Mejorarla Sustentabilidad de Los Recolectores de Base".

In fact, EPR has been flagged as potential facilitator of formalization of the informal sector for "inclusive waste management"[126], wherein the activities of the informal sector and formal waste management system complement each other[127].

Political will is necessary for the integration of the informal sector[128]. Luckily, Chile's regulators are seemingly cognizant of the importance and opportunity in incorporating its informal sector. "Ley Marco para la Gestión de Residuos, la Responsabilidad Extendida del Productor y Fomento al Reciclaje," or the Framework Law for Waste Management, Extended Producer Responsibility and Development of Recycling, explicitly calls out for the inclusion of "recicladores de base," through a "set of mechanisms and tools for training, financing and formalization aimed at enabling integration full use of waste pickers in the management of waste, including in the management systems in the framework of Extended Producer Responsibility," and including them, along with producers, consumers, academics, NGOs, and waste managers, in consultations for setting decrees, establishing goals, evaluation criteria, and in developing environmental education programs[129].

The law does require them to be registered as a base recycler, and must be certified by the National Certification of Labor Competences. But it makes the provision for them to be able to register without having this certification in the first five years of the law.

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[126] Panate Manomaivibool, "Extended Producer Responsibility in a Non-OECD Context: The Management of Waste Electrical and Electronic Equipment in India," *Resources, Conservation and Recycling* 53, no. 3 (January 2009): 136–44.

[127] O.O. Oguntoyinbo, "Informal Waste Management System in Nigeria and Barriers to an Inclusive Modern Waste Management System: A Review".

[128] Ellen Gunsilius, "Role of the Informal Sector in Solid Waste Management and Enabling Conditions for Its Integration Experiences from GTZ," 2010, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.395.2996&rep=rep1&type=pdf

[129] "Política de Inclusión de Los Recicladores de Base 2016-2020".

It makes the Ministry of Environment responsible for creating a labor competency project that will be aimed at the base recyclers acquiring the skills and necessary to manage waste according to the current regulations, and enable them to obtain the required certification.

A separate policy issued by the Ministry of Environment, "Política de Inclusión de Recicladores 2016-2020," the 2016-2020 Recycler Inclusion Policy, is more specific about objectives for including base recyclers in the waste management system across social, economic and environmental axes. Its specific objectives are:

i) To account for their environmental contribution
ii) Advance the inclusion of recyclers in waste management
iii) Protect their health from the health and labor risks inherent in waste management
iv) Certify their work skills
v) Identify and develop economic instruments to promote inclusive recycling
vi) Strengthen their technical and business capacities
vii) Promote inclusive business chains
viii) Promote a "decent" work culture (labor rights and sanitary conditions) across the value chain of recycling
ix) Identify and economically characterize them (through databases)
x) Strengthen the social capital of their organizations, and their ability to access social programs and policies
xi) Achieve greater social recognition for their work
xii) Identify alternative employment routes, as they expect that inclusion and formalization might increase the attractiveness of the job and therefore size of

the labor force; and at the same time, the new regulations could make some recyclers unable to participate.

The policy recognizes that with the passing of the EPR law, the base recyclers will compete with other waste management providers, so it is essential to

> *"generate conditions of equality, recognize their environmental contribution, and enhancing their work and that of their families.[130]"*

4.4.3 Social enterprises formalizing the informal sector

A number of private players have recognized the real need and also the market opportunity in formalizing this sector, and are employing technology to do so. ReciclApp is one such social enterprise which is acting as an interface between the recyclers and households and businesses. It "seeks to optimize and improve the recycling process in Chile, matching people who have reusable material, with recyclers willing to remove this material and market it freely[131]". Individuals, businesses, and institutions who have the free application on their smartphones can declare specific numbers of cans, boxes or bottles they wish to get rid of, and choose a date and time period for pickup. ReciclApp uses the data to create and print out collection routes for the collectors they work with. In February 2017, 200 collectors were working with ReciclApp across Chile, picking up waste from about 1,000 app users in the country. According to the company, recyclers who work with ReciclApp have more than doubled their income from an average of USD $100 USD to USD $250 per month. They also have contracts with cities in Chile,

[130] "Política de Inclusión de Los Recicladores de Base 2016-2020".

[131] "Acerca de La Aplicación," ReciclApp, n.d., http://reciclapp.cl/. (Translated)

including Santiago, which pay ReciclApp on average USD 1,200 per month, as their service reduce the cities' garbage collection expenses[132].

Plastic Bank is another such social enterprise that, in their own words, "empowers recycling ecosystems around the world[133]." Its co-founder, Shaun Frankson, said in a phone interview that "most plastic recycling supply chains are arguably treating collectors as slave labor because buyers can negotiate down to the cheapest price possible.[134]" Plastic Bank is attempting to provide a price protection through promoting a market for its trademarked "Social Plastic," which it verifies provides a negotiated and enforced premium for the collector.

Collectors bring their collected items to a recycling center or a processor, and both sides verify the type of material and the amount sold. An exchange is made and recorded on the ledger, which could be on paper, or if it is through its phone-based application, is on the blockchain, at a pre-determined above-rate, consistent price. The processers then either sell the material to another verified recycler in the supply chain, or turn it into rPET pellets themselves. As all of these transactions, movements, and transformation of the plastic waste is verified by two sides on one system, Plastic Bank claims that the end recycled result, Social Plastic, is verified to be recycled, and ethically sourced as it paid its collectors an above-market price for collecting. They have

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[132] Tomas Urbina, "Chile's 'Uber of Recycling' Is Sparking a Recycling Revolution," *Motherboard*, February 20, 2017, https://motherboard.vice.com/en_us/article/jpaqn8/chiles-uber-of-recycling-is-sparking-a-recycling-revolution.

[133] "Plastic Bank Stops Ocean Plastic While Reducing Povery," Plastic Bank, n.d., https://www.plasticbank.org/what-we-do/.

[134] Frankson Shaun, Interview with Shaun Frankson of Plastic Bank, Phone, May 2, 2018.

entered into partnerships with consumer brands such as Henkel to ensure that there is demand for Social Plastic, and are currently operating in Haiti and Philippines.

Before adopting the blockchain, Plastic Bank was relying on pen and paper for the records of the transactions, which could be destroyed or manipulated. Now, even though the blockchain technology is delivered on a private cloud server, they have to rely less on trusting the individual points in the plastic supply chain, as the transactions are all recorded on two sides and cannot be manipulated. Plastic Bank said that the switch to the blockchain technology has the added advantage of providing a financial record and a financial system for its largely unbanked collectors, who are paid in digital tokens for their collection, as opposed to cash, which can be a liability for them in the high-crime neighborhoods they operate in[135].

Currently the system identifies the material based on plastic type, color, weight etc. When asked if it could also capture brand/ producer information of the product, which would be relevant if the app was used as an implementing partner for EPR schemes, Shaun said it would be possible. It would come with the additional cost of time that identifying and sorting a product by brand would require, but it is operationally and technically it is a small change in an otherwise expressed and functioning system.

[135] Shaun Frankson, "Plastic Bank Deploys Blockchain to Reduce Ocean Plastic," IBM.com, n.d., https://www.ibm.com/blogs/systems/plastic-bank-deploys-blockchain-to-reduce-ocean-plastic/.

Part V: Innovating governance for innovative policy

5.1 Need for oversight and auditing system for PROs

Verification of material flow is one of the main challenges with EPR. According to the Chilean Ministry of the Environment, it will be necessary to have information about the product at each stage of the waste management. According to their report on EPR implementation, the data logging interfaces must

> *"correspond to the entrances and exits of each contracted stage (collection, collection, classification, pre-treatment, valorization); especially...after the collection (to determine the collection rate and quantities by sectors) and at the entrance to the valuation stage (to determine the valuation rate)."*

These data will be compared between the collector and the valorizer to ensure enforcing, but the records of

> *"all the intermediate stages are equally important, to verify the traceability of the residues and the reliability of the the data.[136]"*

At the same time, the Ministry seems to be apprehending the challenges that verification of material flows across the value chain would raise, and recommended that the PRO to collect and process this information before presenting it in a consolidated manner to the auditing authorities "in order to avoid an overload of work by the MMA and to avoid "cemeteries of data"."

Additionally, the literature suggests there are some anti-trust concerns with PROs and EPR. Germany's Green Dot/ Duales System Deutschland (DSD) was identified with

[136] Ecoing, "Evaluación de Impactos Económicos, Ambientales y Sociales de la Implementatión de la Responsabilidad Extendida del Productor en Chile, Sector envases y embalajes" (Ministerio del Medio Ambiente, 2012), http://portal.mma.gob.cl/wp-content/doc/Impactos-envases-y-embalajes-2012.pdf.

raising antitrust concerns, mainly due to institutional arrangements between DSD and associated waste-recovery firms in that established firms might leverage DSD to limit existing competition and extract rents from upstream firms or to exclude potential rivals[137]. The very flexibility a cooperative PROs provide firms (for meeting EPR policy obligations) creates an additional potential for collusion and market power[138], which implies that PROs could have anti-competitive impacts in the forms of price gouging and facilitating collusion[139].

What does this mean? Take for example, Aluminum, which is used in a variety of different products and is infinitely recyclable. But say it is most easily recollected in the form of Aluminum beverage cans. When the collective PRO of canned beverage producers controls the waste supply, they can control the supply of Aluminum to recyclers, and therefore exert market power in an unexpected way.

5.2 The need for a system that includes, legitimizes, and protects base recyclers

A 2018 study evaluating the impacts of introducing informal recyclers to the waste management system in Santiago concluded that the target 20% inorganic material recovery rate cannot be achieved by solely focusing on the drop-off collection system (PLs, PVs) because of "the overwhelming number of stations necessary to reach the

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[137] Anthony Heyes, "Is Environmental Regulation Bad for Competition? A Survey," *Journal of Regulatory Economics* 36, no. 1 (June 4, 2009): 1–28.

[138] Margaret Walls, "Extended Producer Responsibility and Product Design Economic Theory and Selected Case Studies" (Resources for the Future, March 2006), http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.540.7259&rep=rep1&type=pdf.

[139] Pierre Fleckinger and Matthieu Glachant, "The Organization of Extended Producer Responsibility in Waste Policy with Product Differentiation," *Journal of Environmental Economics and Management* 59, no. 1 (January 2010): 57–66.

target and the difficulties in managing this type of station[140]". The researchers concluded it was mandatory to include the informal sector to meet these goals.

As such, it is not clarified where or how the base recyclers are supposed to operate in the EPR-conforming waste management system. The law says that both the PROs, and Municipalities may enter into agreements with base recycler, but does not make them liable to do so. It is not clear if in the absence of such agreements, a certified base recycler would have the legal right to collect waste in competition with the PROs and Municipalities, and the right to recycle it. Their interface with the system has not been defined, protected, or adequately strengthened. Without explicating what their role and responsibilities will be in the waste management chain, and surfacing their impact on it, is possible that they may not have a way to intervene with the waste supply chains in the fair and dignified manner than the Ministry of Environment hope that they will have.

5.3 A worthy vision for Chile's EPR: an integrated, inclusive, and transparent system

If leveraged correctly, a public permission blockchain could be an effective and empowering technology for waste management, and more specifically, for EPR law implementation. A blockchain is "an open, distributed ledger that can record transactions between...parties efficiently and in a verifiable and permanent way"[141]. It is a continuously growing list of records, called blocks, which are linked and secured using cryptography. Each record or block on the chain contains information about the previous record, timestamp, and transaction data. A blockchain is typically managed by a peer-to-peer computer network that collectively validates new records in adherence with a

[140] Ailyn C. Rojas et al., "The Potential Benefits of Introducing Informal Recyclers and Organic Waste Recovery to a Current Waste Management System: The Case Study of Santiago de Chile," *Resources* 7, no. 1 (March 2, 2018), http://www.mdpi.com/2079-9276/7/1/18.

[141] Marco Iansiti and Karim R. Lakhani, "The Truth About Blockchain," *Harvard Business Review*, no. January-February 2017 (n.d.): 118–27.

protocol, and especially when publicly available, removes the possibility that records could be retroactively changed without it being recorded. It is secure by design and makes decentralized consensus possible[142]. While most of the press and attention on blockchain has been for one of its applications, the crypto-currency Bitcoin, it can be uniquely useful in situations where trust is paramount, such as identity verification, food traceability, or other record or contract management, often called smart contracts.

Some waste management providers and companies have already deployed wireless sensors that can sense, measure and process the state of their environment, and actuate based on the input, across the waste stream in an interconnected so-called "Internet of Things (IoT) solutions". Examples of this are "smart" dumpsters with fill-level sensors that can read the kind and quantity of product disposed, signal to the collection agency when they are full. These technologies, and their linked data, could offer municipalities and governments considerable support in their waste management systems, and more importantly, in implementing EPR-like schemes. The Ellen Macarthur Foundation recommended in its New Plastics Economy 2016 report "that an image recognition system could be linked to a database holding the main characteristics of each item, and could, for example, be linked to EPR systems to couple the producers' contributions to the real costs of recycling its packaging.[143]" If the data from these distributed waste delivery points was integrated, especially on a tamper-proof ledger like a blockchain, it would allow waste managers to optimize collection and sorting. In fact, the French Railways (SNCF) implemented a project in which each bin in a station used Bluetooth to update the quantities of type of waste in it, and which waste managers collected it to a blockchain, which helped them optimize the waste

[142] Siraj Raval, *Decentralized Applications*, 1st ed. (O'Reilly Media, Inc., 2016).

[143] Ellen Macarthur Foundation, "The New Plastics Economy – Rethinking the Future of Plastics".

management contracts, yielding 2,000 Euros in savings in one month of implementation[144].

It is possible to create a system in which producers, retailers, IoT-enabled waste collection points, base recyclers, collection centers, classification points, recyclers, and even the final users of the recycled plastic could record the product transfers (with a QR code printed on the product) on a publicly available permission-based blockchain, which any agency such as the Ministry of Environment, or an interested international environment nonprofit such as Ocean Conservancy, or even concerned citizens could access and decrypt with permission. The blockchain would also pay tokens at a predetermined rate for collecting and sorting to the recyclers, which could be converted to local currency, or be used digitally to pay for goods or services, as in Plastic Bank's system. If a product ends up as litter, anyone could use its QR code to determine from the blockchain where in the trail it was left behind, and deliver it to a QR-code reading delivery point that would capture it back in the system, and presumably, citizens could be rewarded in "clean city" tokens for doing so, which would further incentivize such behavior.

In fact, in their Masters thesis in 2017, Manish Lamichhane proposed a blockchain-enabled smart waste management system, and its technical architecture[145]. But their

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[144] "Data-Tritus - Comment La Blockchain Simplifie Le Tri Des Déchets," Digital SNCF, June 6, 2017, https://www.digital.sncf.com/actualites/data-tritus-comment-la-blockchain-simplifie-le-tri-des-dechets.

[145] Manish Lamichhane, "A Smart Waste Management System Using IOT and Blockchain Technology" (ITMO University, 2017), https://www.doria.fi/bitstream/handle/10024/143751/PERCCOM_MASTERS_THESIS_ManishLamichhane_20170720_final.pdf?sequence=2.

proposal did not realize the potential of such a system for a regulation like EPR and with the integration of product inventories, this system could very effectively track the supply chain of products as they turn to waste and are valorized.

5.4 Advantages of implementing blockchain-enabled smart EPR system

The main advantage of using a blockchain as opposed to a distributed database across the various nodes is that the onus of trust and reliability would be taken out from the PRO and the government, as records on such a system cannot be manipulated. In fact, one major function of the PRO is to record, process, and maintain records of product flows, and such an end-to-end integrated blockchain solution could almost negates the need for an entity to do this. With the blockchain in place, the PRO could focus on monitoring the flows, and correctly incentivizing the pay-offs (through changing the pay-offs in tokens for material) at different nodes in case the system is not collecting or valorizing the waste as it should.

Another benefit is that such a system would be a demonstrable way for the government to actuate on its promise of including the base recyclers in waste management. A transparent system like this would ensure that their contributions are appropriately rewarded and recorded.

5.5 Risks and Costs of implementing a blockchain-enabled smart EPR system

The biggest risk of such a system are on two accounts: cost, and adoption. Each transaction or record logged on a blockchain has an associated cost, which can fluctuate and also ranges on the type of platform the blockchain would be hosted on. For context, the average transaction cost on the oldest and one of the most trusted blockchain platform, Ethereum, was USD 0.44 at the time of writing in May 2018, having come down from its historical peak of USD 4.15 in January 2018[146]. Given that there are nearly 7 billion plastic PET bottles in Chile that will be sold in 2019, the costs of recording several transactions per bottle across its waste management cycle would be too high on Ethereum. Another option is Stellar, which is a newer and faster platform with a considerably cheaper per transaction rate, which is currently at USD 0.00000395392/ transaction. Theoretically, if there were 6 points at which an exchange of a PET bottle could be recorded on the blockchain (producer, retailer, base recycler, collector, recycling factory, and buyer of rPET), the cost of recording material flows for all 7 billion PET bottles at Stellar's current prices is about USD 170,000, which is comparable or maybe an order of magnitude lower than the costs of hosting a database solution on servers[147]. To be fair, the rates could rise, as they have before for Ethereum, but even a 20-fold increase would be within competitive range. Also, this is accounting for 100% of the bottles going through the system, when the recycling rate is likely to be around 30%.

Blockchain is not a widespread or easily understood technology, and that can be a deterrent in its adoption. The good news is that it does not have to be understood by the various participants in the value chain for it to be easy to use. As long as its various interfaces are customized to suit the participants', it will be experienced as any other application on a smart phone that billions of people are using today. Shaun Frankson of Plastic Bank mentioned that while the low levels of literacy among the collectors was the most significant challenge they face with making their technology usable, and they are specially designing the interface for this, and will be releasing customized and

[146] "Ethereum Avg. Transaction Fee Historical Chart," Bit Info Charts, n.d., https://bitinfocharts.com/comparison/ethereum-transactionfees.html.

[147] Own estimations, calculations and comparisons

localized versions of the app that they are developing using user-driven research and design with their technology partners IBM.

5.6 Setting precedent with the blockchain

A number of countries have banned blockchain based crypto-currencies for concerns of their association with illegal activities, but several countries are employing its underlying blockchain technology for their operations[148]. Dubai hopes to be the first city government that is completely operates on the blockchain by 2020, and has already launched a blockchain-powered system for financial transactions in real-estate purchases and trading, real-estate contracts, and which connects homeowners and tenants to electrical water, and telecommunications utility providers[149]. Estonia was among the first countries to adopt the blockchain for government use, and has used it to transform the country's database across sectors such as security, health, judiciary, and has also created a blockchain-based national identity management system, ID-kaart[150], with the hope to improve timeliness and quality of public service delivery to its citizens.

Chile recently also became the first country in South America that pioneered use of blockchain in public records. Chile's Ministry of Energy and the National Energy Commission announced in April 2018 that the country's energy sector statistics, already available on a digital platform called Energía Abierta (Open Energy), will also be

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148 Andrew Nelson, "Cryptocurrency Regulation in 2018: Where the World Stands Right Now," *Bitcoin Magazine*, February 1, 2018, https://bitcoinmagazine.com/articles/cryptocurrency-regulation-2018-where-w orld-stands-right-now/.

149 Suparna Dutt D'Cunha, "Dubai Sets Its Sights On Becoming The World's First Blockchain-Powered Government," *Forbes*, December 18, 2017, https://www.forbes.com/sites/suparnadutt/2017/12/18/dubai-sets-sights-on-becoming-the-worlds-first-blockchain-powered-go vernment/#150a1a6c454b.

150 "We Have Built a Digital Society and so Can You," E-Estonia, n.d., https://e-estonia.com/.

recorded on an Ethereum Blockchain[151]. The officials at the announcement said "…we have decided to use blockchain as a digital notary, which will allow us to certify that the information we provide in the open data portal has not been altered or modified and left unalterable record of its existence." And, "Public information is an important input for decision making… our users use this information to decide technical, economic and labor aspects… through the use of this technology, we will raise the levels of trust of our stakeholders, investors and the general public that consumes the data.[152]" It should be noted that this recording of the energy statistics is not happening through IoT devices, but through (presumably humans) entering the information as it is collected and aggregated on the Open Energy platform, so there is still a level of error possible. It also appears this is not a distributed ledger (i.e. it I without multiple nodes), which does not make for a very trust-worthy application of blockchain. Still, this shows that Chile has an appetite to experiment with and apply the blockchain technology.

If the Ministry of Environment in Chile is committed to holding producers accountable for the waste they are creating, and to increasing visibility and opportunities for base recyclers, the blockchain can be a powerful ally in EPR implementation. More than just being a strong signaling mechanism, it will bring radical transparency to the lifecycle of products and to Chile's waste management. Producers are already employing the blockchain to hold their suppliers responsible for quality along the supply chain[153], but

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151 "Conoce Nuestros Datos Certificados," Energía Abierta, n.d., http://energiaabierta.cl/visualizaciones/blockchain/.

152 Helen Partz, "Chile's National Energy Commission Launches Ethereum-Based Pilot For Energy Data," Coin Telegraph, April 7, 2018, https://cointelegraph.com/news/chiles-national-energy-commission-launches-ethereum-based-pilot-for-energy-data.

153 Zandi Shabalala, "De Beers Tracks Diamonds through Supply Chain Using Blockchain," *Reuters*, May 10, 2018, https://www.reuters.com/article/us-anglo-debeers-blockchain/de-beers-tracks-diamonds-through-supply-chain-using-blockchain-idUSKBN1IB1CY.

no such application of blockchain exists for governments to hold for producers in an economy responsible for their products and waste. If Chile implemented such a system, it would make it another first in its cap and would be in line with the narrative of it being an innovative country committed to its stated goals.

Part VI: Recommendations

In Spanish, the word for collect is *recolectar*, and predictably, it came up over and over again in Chilean documents pertaining to the law while researching for this thesis. But another translation for *recolectar* is to harvest, and the double-entendre is very apt here. With a thoughtfully designed, technically sound, and well-managed system, producers, consumers, citizens, and local governments could "harvest" the plastic already sowed in our world to derive more value out of it and reduce its ecological footprint. Counting is a big part of harvest, so a system that records, measures, and corrects itself is important. The following recommendations are relevant to Chile's EPR implementation:

1. While a coordinated effort of collection and sorting will ensure a steady, growing, and quality-controlled supply chain for the recycling industry, recycled plastic's price and demand will be subject to virgin plastic's. President Bachelet had remarked that EPR was passed to reduce pollution and to stimulate the economy through the recycling sector. Chile should consider extending its carbon tax to virgin plastics produced or imported in the country to give recycled plastics market a better opportunity to compete.
2. Collective PROs are the most functional approach, and one that would be able to take advantage of economies of scale, but monitoring, oversight, and a way to raise and address complaints will be required to ensure that their increased control of the waste management does not exploit the recycling market or become a barrier for entry or competition for other producers
3. Clarify exactly where and how the informal base recyclers can continue to provide their service and make their income through waste management. Care should be taken that whichever system is implemented, allows them to work, records their contribution, and treats and pays them fairly.
4. Connect "smart" (IoT) delivery points, base-recycler facing-mobile phone applications, and various producers', retailers', and recyclers' inventory systems

on an integrated public permission blockchain that tracks the flow of products, and measures and rewards every agent's contribution to proper waste management in a transparent, reliable, and ground-breaking way.

5. Finally, encourage practices and consumption models that reduce or eliminate waste over recycling. In the case of plastic waste, stem the rising tide of PET bottles through regulating the sale of bottled water, and ensuring ready availability of safe drinking water. Public perception of water quality is an important factor in this regard, so monitoring and publishing of water quality reports from reliable sources will be important to nudge this behavior.

Conclusion

Siempre,
productos manufacturados, medias, zapatos,
o simplemente aire infinito,
habrá entre mis pies y la tierra
extremando lo aislado y lo solitario de mi ser,
algo tenazmente supuesto entre mi vida y la tierra,
algo abiertamente invencible y enemigo[154].

- Pablo Neruda
  (de "Ritual de mis Piernas," in en su libro de poesía, "Residencia En La Tierra")

Always,
manufactured products, socks, shoes,
or simply infinite air,
there will be between my feet and the earth
stressing the isolated and solitary part of my being,
something tenaciously involved between my life and the earth,
something openly unconquerable and unfriendly[155].

- Pablo Neruda
  (from "Liturgy of my Legs" in his book of poetry, Residence on Earth)

This paper modeled the costs of recovery and recycling of post-consumer PET bottles under the proposed Extended Producer Responsibility (EPR) law in Chile. For 2019, at a 13% recycling rate, the cost per bottle was estimated to be between CLP 0.63 and CLP 0.70, representing less than .1% of the cost of a PET beverage bottle sold in the market, which is comparable with similar efforts around the world. Demand for PET

[154] Pablo Neruda, "Ritual de mis piernas," in *Residencia en la tierra*, n.d., http://www.literatura.us/neruda/r1_3.html.
[155] Pablo Neruda, "Ritual of My Legs," *DM Du Jour* (blog), March 21, 2016, https://dmdujour.wordpress.com/2016/03/21/pablo-neruda-ritual-of-my-legs/.

bottles is inelastic[156], so especially at this very marginal price increase, EPR implementation should not significantly affect the packaged beverage industry in Chile.

The paper also noted the dynamics of the recycled PET (rPET) market, and the role that packaged beverage producers play in it. Currently food and beverage packaging constitutes 70% of the global demand for PET, but only 3% of packaged beverages are made of rPET. As beverage producers in Chile will be managing and operating the downstream supply of post-consumer PET, they have an opportunity to create a circular supply chain by using the rPET in place of virgin PET in their bottles. This would be cost-efficient for them and significantly more sustainable for the environment.

Informal waste pickers, or base recyclers, have a critical, invisible, and perilous role in waste management systems around the world. Chile's EPR law intends for the implementation to be inclusive of them, but there is no formal requirement on the producers or on municipalities to employ them, nor any point clarified in the waste management value chain where they are authorized to provide their services. Chile's 60,000 base-recyclers have spent on average 12 years on this job. They have unique skills and knowledge in this domain which will be critical in its transition. Elsewhere, not including the informal sector has led to the failure in EPR implementation.

If Chile is indeed committed to including base recyclers, and to obliging producers to be accountable for their products, one way it can achieve both these aims is through a public blockchain in which producers, retailers, IoT-enabled waste collection points,

[156] Andrew Stevens, "Taxes on Bottled Water Are Better at Raising Money than Reducing Litter," *LSE US Center* (blog), n.d., http://blogs.lse.ac.uk/usappblog/2016/12/06/taxes-on-bottled-water-are-better-at-raising-money-than-reducing-litter/.

base recyclers, collection centers, recyclers, and final users of the recycled materials can record the product transfers (with a QR code printed on the product). The blockchain would also pay tokens for collecting and sorting to the base recyclers, which could be used as or converted to currency. Such a system would measure their impact, improve their legitimacy, and provide income security, while also giving a straightforward method of reviewing producers' performance.

EPR was proposed 30 years ago, but it is still an underutilized policy approach that holds a unique promise in its ability to align the interests of industry, local and national governments, multilateral agencies, non-government organizations, the citizen-consumer, and the biosphere. It is an innovative policy approach that needs an innovative, or some might even say, radical management solution such as the blockchain.

Chile's environmental regulatory efforts started as part of its becoming a part of the OECD. If it becomes the first country to adopt the blockchain in such a manner, it would strengthen its narrative of being a pragmatic pioneer, especially as it looks to gain higher global status and recognition as an innovation powerhouse which is economically independent from the copper commodities market. And while plastic will remain, as said Chile's beloved poet, "tenaciously involved between our lives and the Earth," perhaps such a transparent and inclusive system could transform it to be something openly conquerable, and maybe even friendly.

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