Implementation and Evaluation of an Incentivized Blockchain-Based Deposit-Refund System

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Niklas Sauer

Abstract

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Acronyms

dApp	Decentralized Application
DPG	Deutsche Pfandsystem GmbH
EAN	European Article Number
HPE	Hewlett Packard Enterprise
VerpackV	Verpackungsverordnung

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1 Introduction

1.1 Motivation

Compared to glass, plastic or aluminum packaging represents a lightweight and durable alternative. The impact of lightweight materials on shipping costs is non-negligible and has therefore been leveraged in the beverage industry for the past 30 years. Simultaneously, the quote of reusable bottles (Mehrwegflasche) has steadily fallen (from 72% in 1991 [11, p. 1] to 43% in 2015 [12, p. 4]), which prompted German lawmakers to introduce a system of returnable one-way bottles (Einwegflasche) in 2003 on which a deposit is paid [24, p. 53].

Contrary to expectations [18, p. 10], this regulation has not stopped the influx of one-way bottles but has rather benefitted bottlers. Whenever consumers pollute by leaving behind one-way bottles, an instant 25 cent profit – assuming that no one else has returned them – is generated for the producer. This passive profit was estimated to have reached up to 192M€ in 2011 alone [21, p. 245].

Ideally, this pollution of the environment should be punished by splitting non-claimed deposits of one-way bottles between environmental agencies and those consumers who regularly purchase reusable bottles, which save more resources. As a further consequence, those consumers who repeatedly neglect to return their one-ways should be required to pay a higher deposit. Such a revised approach can hopefully maximize the number of returned one-way bottles and effectively steer users towards reusable ones. Otherwise, a further decline may be inevitable and is shown to have had a direct negative impact on global warming, in addition to the excess amount of waste produced hereof [2].

When considered on a case-by-case basis, this problem inherently deals with deposits of very low extrinsic value. Moreover, such a system has to manage account balances and track the movement of value, increasing the appeal and likelihood for external attacks. Therefore, implementing the proposed approach by utilizing smart-contracts and micro-transactions on the Blockchain may come to mind upon choosing the underlying architecture. But how does such an implementation look like; are there special considerations to be made?

1.2 Goals and Scope

Since no research on the feasibility of this approach has been undertaken for an application as specific as this one, the study focuses on the end-to-end development process, including design, implementation and deployment. The objective of the research is to guide Hewlett Packard Enterprise (HPE) and interested parties alike in developing a mindset suitable for migrating applications onto decentralized platforms and evaluate if this Blockchain-based implementation can withstand the requirements of an incentivized deposit-refund system. The results are relevant as they reduce the go-to-market time of the previously outlined solution to stop the influx of one-way bottles, which in turn reduces pollution and warming of the earth (comp. 1.1), a serious concern to today's society. Moreover, HPE can offer more profound Blockchain-related consulting services through the insights gained.

It shall be explicitly noted that the study does not cover analyzing the effectiveness of employing such a system (i.e. reducing the usage of one-way bottles) or verifying wether this represents the best possible approach. Similarly, the legal framework and ethical questions pertaining to its usage are disregarded.

1.3 Thesis Overview

Chapter 2 reviews the relevant literature and is intended to answer all descriptive research questions that help define the project variables. The key concepts are then applied in chapter 3 as part of the architectural overview derived from the functional requirements of an incentivized deposit-refund system given earlier in the chapter. At the same time, the criteria to evaluate the forthcoming implementation are selected. Chapter 4 then describes the procedure to implement the solution, after which the actual evaluation may take place in chapter 5. Chapter 6 uses the results to draw a conclusion, discuss probable alternatives, as well as any limitations encountered during the study. Finally, chapter 7 summarizes the thesis's goals, methodology and results and is followed by chapter 8 to highlight interesting related research opportunities.

2 Theoretical Framework

2.1 Deposit-Refund System for Bottled Beverages in Germany

2.1.1 Legal Basis

Anticipating the depletion of capacity in disposal sites and due to the considerable share in waste generated by packaging [1] [18, p. 2], German federal government enacted an ordinance regarding the avoidance of packaging waste (*Verordnung über die Vermeidung von Verpackungsabfällen*, short: *Verpackungsverordnung (VerpackV)*) in 1991 which stipulates that packaging [27, § 1]:

- must be minimised to an extent necessary for protection and marketing of goods
- must be reused where possible
- must be recycled if reuse is not applicable

These objectives were supported by introducing the:

Obligation to take back packaging

Producers and distributors of packaging are obliged to take back packaging free of charge, restricted to those goods of type, shape, size and material found within their stock [27, §§ 4-6]. Distributors with a retail area of less than $200m^2$ are further exempted to the same brands. This duty may be only be ignored if a distributor participates in a system which ensures the periodical collection of waste [27, § 6], known and implemented as a refuse recycling system (*duales System*) in 1990 [18, p. 3].

Obligation to levy deposits on beverage packaging [2]

A deposit is to be charged by the distributor that will be refunded to the purchaser upon return of the bottle. This duty is applicable on all levels of trade involving domestic beverages sold in non-reusable packaging (*one-way packaging*) [27, § 7] and

[1] Recycling rate of packaging was below 50% in the early 1990s (20% for aluminium and plastic) [18, p. 2].

[2] Information regarding the assumed effects and critique thereof can be found in [29, p. 630] and [28].

becomes effective as soon as the quote of reusable beverage packaging falls below 72% [1] [27, § 9].

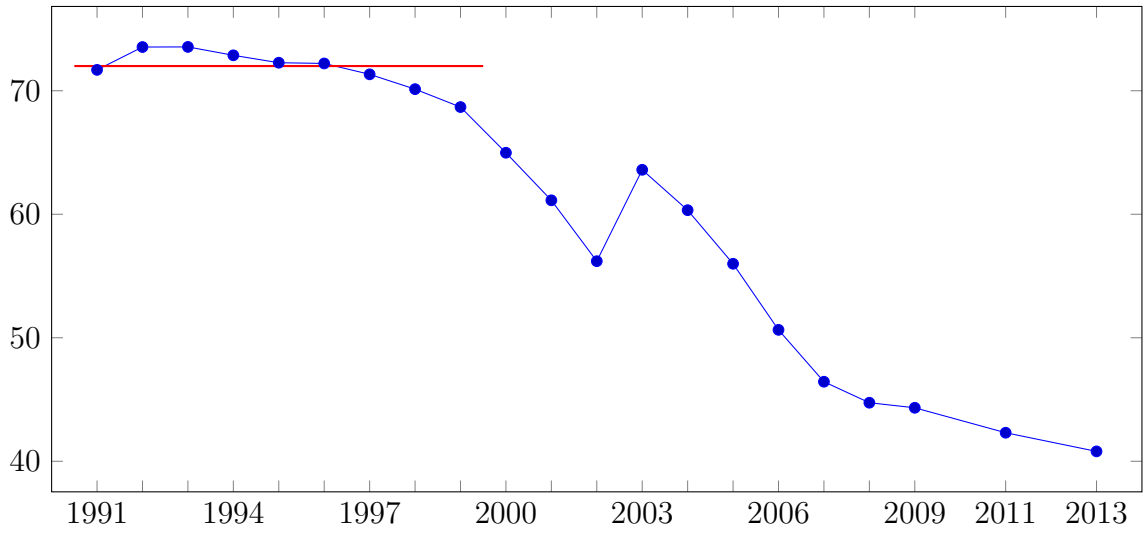

Figure 2.1: Aggregated quote of reusable beverage packaging between 1991 and 2013 [11, p. 1]

Starting in 1997, the threshold to levy deposits has been surpassed steadily (comp. Figure 2.1), requiring an additional assessment of the situation to ensure that the fluctuation does not represent a short-term development [27, § 9] [18, p. 5]. Although obvious at glance, the outcome of a compulsory deposit-refund system only became official on July 2nd, 2002 [24, p. 49], after a lawsuit lead by multiple bottlers and distributors had delayed the initial announcement [13]. Introduction of this mandatory system was scheduled for Jan 1st, 2003 [24, p. 53].

2.1.2 Amendments

The German packaging ordinance underwent several revisions, including a change of title to highlight the importance of recycling [26]. In the following, the most important changes affecting the current state (see Figure 2.2) shall be highlighted.

1998

Trims deposit obligation to those beverages for which the quote of reusable packaging has fallen when compared to 1991, though still necessitates that overall aggregated quote undercuts threshold of 72% [15, pp. 142]. Even though all five segments (beer, mineral water, carbonated soft drinks, fruit juice/non-carbonated soft drinks and wine) have failed this comparison [11, p. 1], juices/non-carbonated soft drinks and

[1] Aggregated quote derived from weighted average of percentages of reusable packaging encountered across individual segments in 1990 [27, § 9] [23, p. 134]

wine are exempted because their decline and market volume has not been regarded significant enough to justify the costs introduced with such a system [18, pp. 6, 9].

figure showcasing development of reusable packing quote in each segment (appendix)

2005

Reduces different deposit classifications to single deposit worth 0.25 € valid for all applicable beverages with a filling volume between 0.1 - 3.0 litres. Furthermore, ecologically advantageous packaging is admitted the same treatment and classification as that of reusable packaging which represents an important shift of thought since the sole utilisation of packaging has been considered inferior to its reuse with regard to all ecological aspects [18, p. 7]. Accordingly, the new goal is to promote the use of ecologically advantageous packaging with a target of 80% market dominance [17, § 1]. This amendment also adds non-carbonated soft drinks and mixed alcoholic drinks to the list of beverages subject to deposits (irrespective of the reusable packaging quote experienced) while simultaneously protecting dietary products from deposits [14, p. 1408] [16, p. 171]. Finally, retailers are required to take back any bottles made from a beverage packaging material (glas, metal, paper and plastic) also sold by that store (brand equality for retail areas of less than $200m^2$ still applies) [18, p. 11]. Previously, return had been limited to bottles of same shape, size [..] and type (comp. 2.1.1). This regulation attempts to stop isolated deposit-refund systems which arose because discounters created their own specially shaped bottles [16, p. 168]. To conform with this change, industry and commerce established the Deutsche Pfandsystem GmbH, responsible for setting up a nationwide deposit-refund system [18, p. 8].

2008

Orders distributors to clearly mark bottles as being obliged to a deposit. Further, distributors are demanded to participate in a nationwide deposit-refund system to enable the mutual settlement of claimed deposits [17, § 9]. Lastly, the exemption for dietary products is reduced to infant nutrition. This acts as a measure to counteract increasingly false product declarations attempting to forego deposits [17, pp. 531] [16, p. 171].

add 2019 amendment

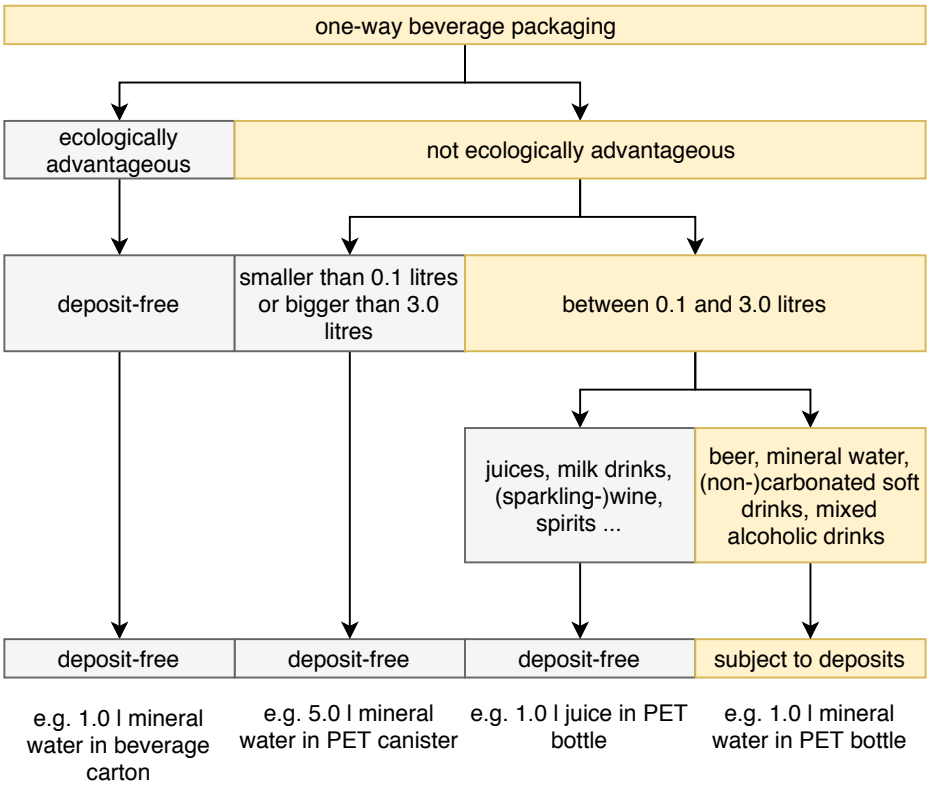

Figure 2.2: Criteria to be considered for deposits (valid until Jan 1st, 2019) [18, p. 9]

2.1.3 Operation

Administration by Deutsche Pfandsystem GmbH

VerpackV simply assumes that a nationwide deposit-refund system will be installed by May 1st, 2006 without further specifying its exact implementation details [14, Art. 2] [17, § 9]. Therefore, Deutsche Pfandsystem GmbH (DPG) has been founded in 2005 to ensure the definition of a standards framework, which includes IT-processes, APIs and a universal security mark identifying one-way packaged bottles on which a deposit is paid (*returnable bottle*). Other tasks concern the management of contracts, certifications and maintenance of a centralised database which stores information about products, participants and reverse vending machines [18, pp. 13]. However, DPG does not have access to purchasing data (e.g. number of sold and returned bottles or total amount of reimbursed deposits). This data is only exchanged between actors of the deposit-refund cycle. Consequently, DPG is not involved in the process of settling refund claims between take-back points and does not act as a central clearing house. It is exclusively responsible for providing a contractual and administrative basis needed to enable such a system [18, p. 14].

figure showcasing universal security mark (appendix)

Roles

As indicated, actors of the deposit-refund cycle (e.g. retailer selling returnable bottles) must register with DPG, accept the contractual basis for the role to be exercised and pay a yearly membership fee in order to participate. The most important roles are [18, pp. 15-16]:

Initial distributor
: Puts returnable bottle into circulation. Inherently tied to role of deposit escrow account manager. Must pay a one-time fee to register a beverage (i.e. an EAN) with DPG's central database. This fee depends on the number of pieces produced within a year for that beverage.

Deposit escrow account manager
: Administrates and disburses money received from levying deposit on returnable bottle. Task may be delegated to a service provider.

Take-back point
: Refunds consumer in exchange for returning bottles subject to deposits. Inherently tied to role of refund claimant.

Refund claimant
: Puts in a claim to be reimbursed for making advance refunds. Task may be delegated to a service provider.

Counting center operator
: Takes over role of reverse vending machine by confirming number of genuinely accepted bottles with a receipt.

Deposit-Refund Cycle

Each buyer of a returnable bottle must directly pay the designated deposit to the seller. This process starts with the initial distributor (step 1 of Figure 2.3) and is repeated for each sub-distributor until the bottles reaches retail which acts as the final distributor to end consumers (step 2 of Figure 2.3). After consumption, the consumer may return the packaging at any retail store obliged to take back the packaging in question (take-back point) (step 3 of Figure 2.3). Return may be performed manually (step 1a of Figure 2.4) or can be automated through reverse vending machines (step 1b of Figure 2.4). The former requires personnel to count the number of returned bottles and refund the consumer accordingly. Following count, the collected bottles must be shipped to a counting center which is responsible for digitally capturing each bottle (step 2a of Figure 2.4). At last, the

bottles will be compressed to eliminate the possibility of repeated refunds. In the case of reverse vending machines, the process of counting, capturing and compressing bottles can take place locally at a retail store (step 2b of Figure 2.4). Alternatively, retailers are permitted to return the packaging to the previous distributor, thereby unwinding the deposit-refund chain. However, this practice is rarely exercised since the packaging will not be reused and transportation would only induce additional ecological and financial strain. Instead, the compressed packaging can be sold directly to recycling companies (step 3 of Figure 2.4) [18, p. 16-17] [3].

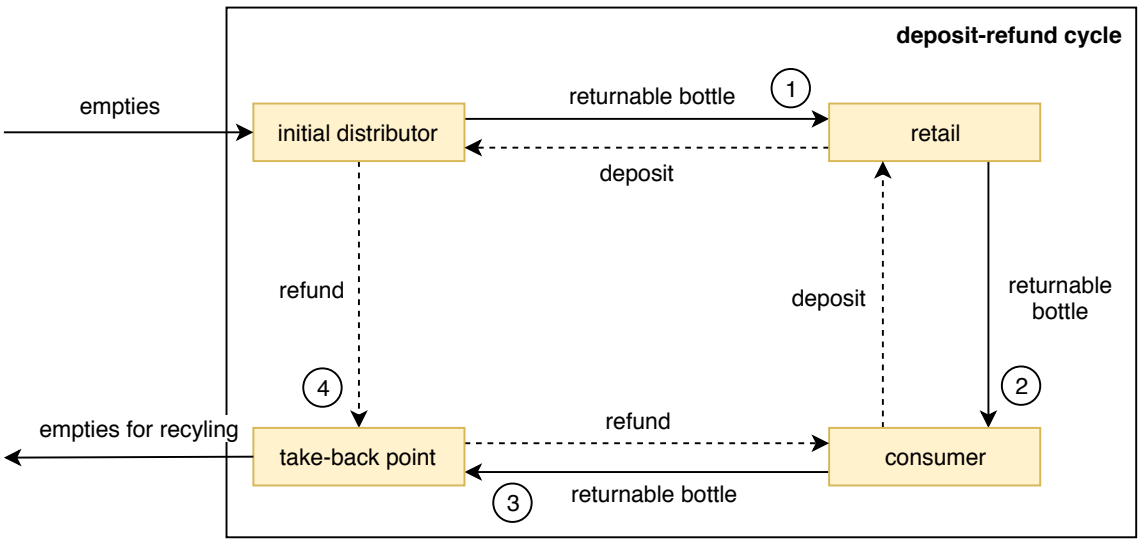

Figure 2.3: Deposit-refund cycle [18, p. 14]

Since take-back points refund consumers independent of a bottle's purchasing location, a settlement process (*clearing*) is required to reimburse retailers for making advance refunds (step 4 of Figure 2.3). This clearing happens by issuing a refund invoice to the initial distributor who can use the deposits originally collected the pay the bill (step 4 of Figure 2.4). Ideally, all accounts are in balance, meaning that all packaging has been returned. Otherwise, a surplus on the part of an initial distributor is to be experienced [18, p. 17].

Refund invoices must also include data representing the number of bottles for which a refund was issued. This data originates from the return process in which each bottle is eventually captured. Capture refers to both validating the universal security mark printed on a bottle's label as well as extracting the European Article Number (EAN) by scanning its barcode. By outfitting reverse vending machines with a network connection, looking up the EAN in question becomes possible, thus ensuring that a deposit for the bottle has been collected beforehand. For each valid bottle, a signed record is then produced and stored on the machine. This data must be retrieved and transmitted within one week. Likewise, retailers receive a similar dataset when relying on a counting center. Finally,

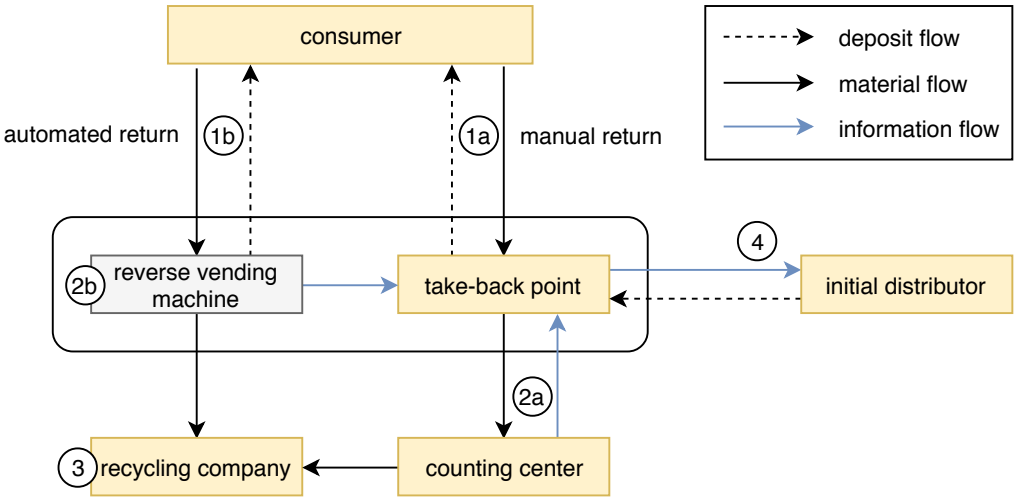

Figure 2.4: Clearing process for manual and automated bottle returns [18, p. 18]

any transmitted data is anonymised by removing the return location and summing up the refunds for each EAN captured. Initial distributors must pay the invoice within ten business days or five-teen calendar days at the lastet [18, p. 18-19].

explain situation surrounding deposits on reusable bottles

2.2 Decentralized Applications

2.2.1 History & Raison d'Être

Johnston's Law states that everything that can be decentralised, will be decentralised [1]. Fittingly, a new model for building massively scalable, successful and profitable applications, known as *Decentralized Applications (dApps)*, is emerging [22, p. 5] [19, pp. 1-2], suggesting that this will also become the fate of the vast majority of web software applications as those follow a centralized server-client model in which individuals directly depend on a central power to send and receive information [22, pp. 7-8].

The architectural structure embodied by the web has not always been as pronounced as is these days. In its early days, people would host personal servers for others to connect to and everyone owned their data. But soon, it was recognised that one individual or group could pay for the maintenance of a server and profit from users that utilize it (eg. [4] or [5]) and since this was easier to the average user, both conceptually and programmatically, the transition to few centralized controlling entities started [22, pp. 14].

Now, users willingly give their data to service providers in return for free usage, trusting them to not misuse or sell the data elsewhere [22, p. 24]. However, Snowden proved that this trust can, has and will be broken as long as we entrust (encrypted) data to central entities which represent a surveillance state's dream [10] [22, p. 25]. In addition, centralized infrastructure and services increase the chances for downtime, censorship and counterparty risk [9, p. 23]. Drawbacks like these, have attributed to the development of dApps, first pioneered by Bitcoin as a currency [19, p. 1] [20, p. 1]. Simultaneously, recent apps (e.g. Uber [6] and AirBnb [7]) attempt to decentralize real world parts of a business by providing a central and trusted data store, foreshadowing the development of decentralized apps beyond pure finances [1] [22, p. 15].

The concept of dApps is meant to take the web to its next [2] natural evolution [9, pp. 34]. Web3 represents the vision of a serverless internet, encouraging applications to incorporate decentralised protocols in order to put users in control of their own data, identity and destiny [8]. As global economy evolves, data will become the primary form of value [22, p. 25], leading the author of [22] to believe that:

> "[dApps] will someday become more widely used than the world's most popular web apps" [22, p. 5]

[1] Supports the blockchain evolution theorem proposed in [25].

[2] Web 2.0 describes the evolution towards user-generated content, responsive interfaces and interactivity [9, p. 34].

2.2.2 Architecture and Components

2.2.3 Platforms

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3 Concept

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Glossary

beverage packaging

Predominantly closed packaging for foods of liquid nature intended for consumption as a drink, excluding yogurt and kefir [27, § 3].

reusable packaging

Packaging intended to be reused for the same purpose after having been used. Characterised by having set up the logistics to take back, clean and refill the packaging. The sole intention or claim to be reused is not valid [27, § 3].