Technical mechanics of a trans-border Waste Flow Tracking solution based on Blockchain technology

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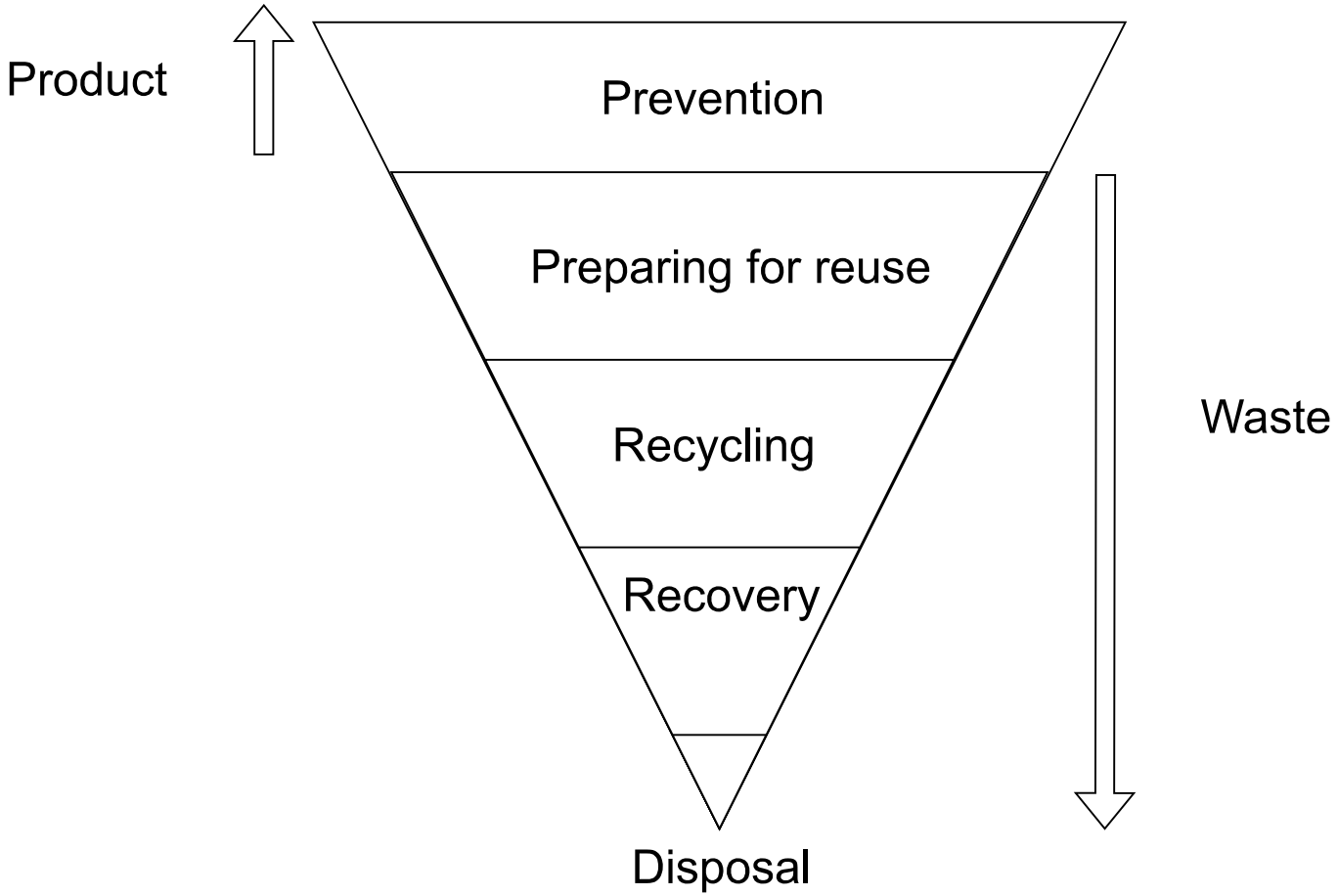
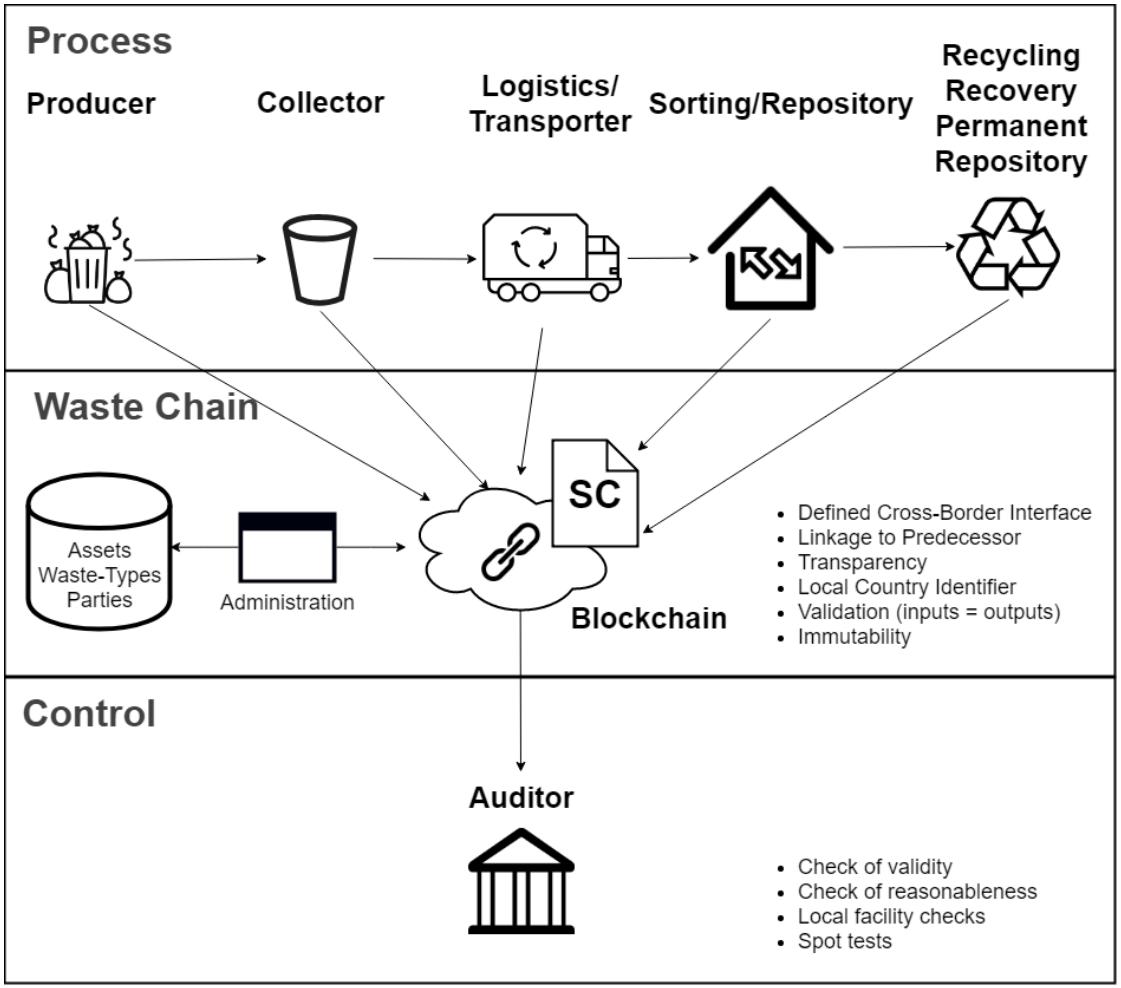
Introduction

- Strong **shift from disposal of waste to recycling** in high-income countries.
- Inadvertently created situation that made **export and misuse of waste lucrative**.
- Process lacks **transparency** and **data-security** in cross-border scenarios.
- Illegal trade and dumping have accounted for an annual resource **loss of 10-12 billion USD** and caused severe environmental and health-related issues.
- Blockchain enables novel approaches and established trust in an environment of **multi-lateral distrust**.
- The proposed solution introduces a **technical concept and prototype implementation** for evaluation.

EU Waste Hierarchy

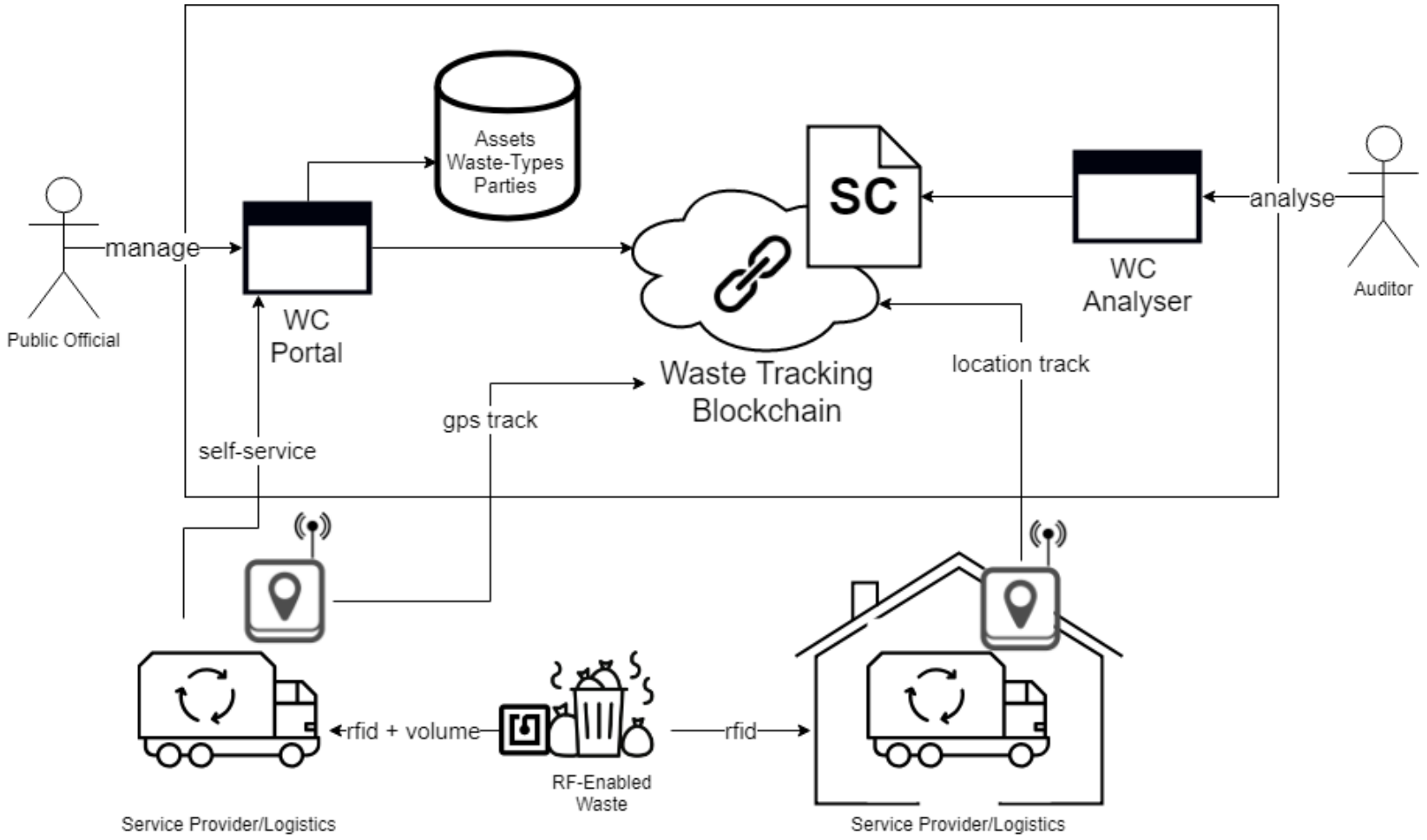


Waste Management Process



- Defines, and stores entities involved
- Stores assets, such as landfills, repositories etc. involved
- Local Waste types and translations of waste types
- Stores a log of all executed process steps with timestamps and waste types, assets and parties involved

Waste Tracking



Proposed Architecture

- **Audit-critical part of the information is stored on the blockchain**
- **Other sensitive and non-disclosable information are stored locally (e.g. by local authorities)**
- **Combines requirements for auditability and data privacy**
- **Audit using big data analysis, providing scheduled reports and immediate altering**
- **Interfaces**
  - Direct blockchain access
  - APIs
  - User Interfaces (also used for administration of off-blockchain data and configuration)

Audit

- **Complements monitoring in each facility and quality assurance measures of each service provider**
- **Detect discrepancies in the collected data using confidence intervals and statistical outlier detection**
- **Examples of detectable irregularities**
  - Facility handling volume mismatches
  - Impossible storage volumes
  - Unusually high number of exceptional termination reasons
  - Impossibly fast transportation
  - Export fraud (waste gets exported to a country officially for recycling, but actually gets burned or dumped)
  - Dumping waste at non-disposal sites (waste is disappearing suddenly)
  - Impossible weight of waste (e.g: lightweight demolition waste)
  - Impossible routes or GPS coordinates

Data Protection

The following data protection considerations were taken into account during the design and prototypical implementation

- No information stored on the blockchain shall identify a person directly (e.g. name, social security number, IP address)
- No personal data shall be stored on the blockchain (e.g. identifier of persons, pseudonyms)
- It shall not be possible to combine information on the blockchain to identify a person (de-anonymization with quasi-identifier)
- No information shall be saved on the blockchain that can be used to profile an entity

Data Model – Waste Transaction Types

Field	Description
produce_waste	Initial transaction to create an amount of waste
merge_waste	Combine two transaction outputs (waste) to one
transport_waste	Move the waste from one location to another
split_waste	Divide waste, usually in two or more different types of waste
terminate_waste	Typically the last transaction of the waste item with a given reason (see domain information)
convert_waste	Convert waste to other type

Data Model – Domain Data

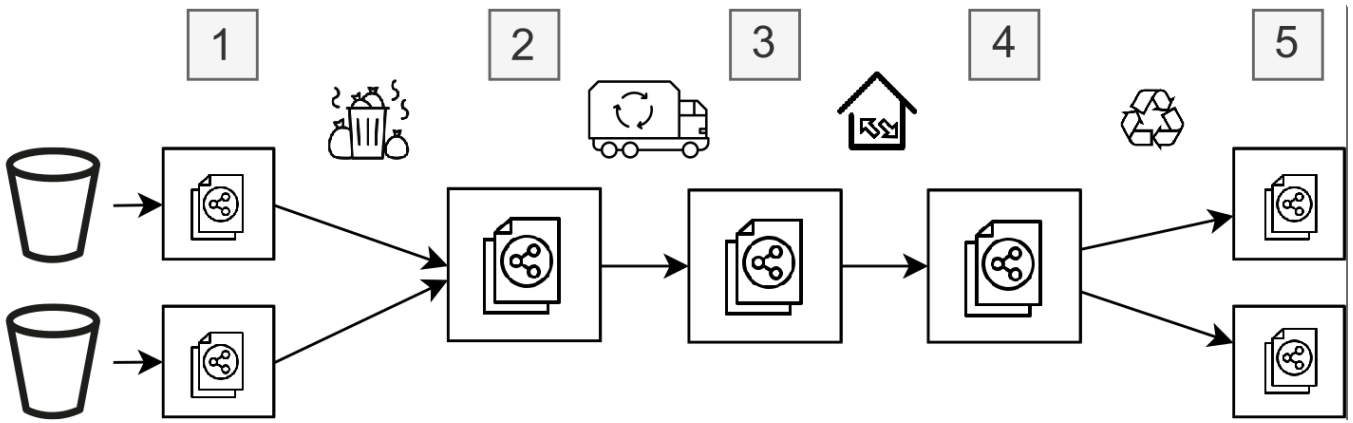
Field	Description
Waste type	Definition of what kind of waste was dealt with
Start time	Timestamp of the start of the transaction
End time	Timestamp of the end of the transaction
Location data	Salted hash of the location information
Carrier type	Type of transportation compound
Volume	Measurement of the waste amount
Termination Reason	Reason for the termination transaction (e.g. recycle, recovery, permanent repository, incineration, exception, escalation)

Data Model –Technical Data

Field	Description
Transaction type	One of the previously defined transaction types
Transaction identifier	Identifies the transaction
Source	Identifies the source transaction
External references	References to an external (usually local) system
Signature	Signature based on the data above

Prototype

- Core of the waste chain prototypical implemented
- Basis for future field trials and academic research
- Built with Truffle Suite, written in Solidity on the Ethereum Blockchain
- Proposed standardized API and message format for waste transactions
- Data entry with simple web client



Evaluation

- **Estimated cost of computation and storage based on example flow**
  - Gas: 195.500 – 195.600
  - Bytes: 350 – 500 (can be reduced by ~48 bytes if only the state is stored)

- **Rough estimate based on European statistics for Germany**
  - Gas cost (current energy prices): USD 280 mio
  - Storage: 400 GB

- **Conclusion: Usage of public Ethereum chain not feasible**

Conclusion & Future Work

- **Automated waste tracking can be done on a large scale**
- **High data-privacy standards**
- **Applied blockchain technology to attack problem of illegal waste**

- **Future Work**
  - Implementation as secondary storage to existing WM-System
  - Design and implementation of a tamper proof mass tracking system
  - Increased data protection using zero-knowledge proofs
  - Establishment of a legal and standards framework for trans-border waste transactions